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Focused Corrective Measures Study/Feasibility Study Report (CMS/FS) for the Wetland Area at Dunbarton Bay In Support of Steel Creek Integrator Operable Unit (U)

CERCLIS Number: 71

SRNS-RP-2012-00252

Revision 1.1

April 2013

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Aiken, South Carolina

CERTIFICATION

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[REF: 40CFR270.11 (d)(1)]

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EXECUTIVE SUMMARY

This document is a Focused Corrective Measures Study/Feasibility Study (FCMS/FS) which discusses remedial action objectives (RAOs) and remedial goal options (RGOs) for the Wetland Area at Dunbarton Bay (WADB) in support of the Steel Creek Integrator Operable Unit (IOU). The goals of the remedial actions are to protect human health and the environment and to mitigate the effects of contamination. The WADB is listed as a Resource Conservation and Recovery Act/Comprehensive Environmental Compensation, and Liability Act (RCRA/CERCLA) unit in Appendix C of the Savannah River Site (SRS) Federal Facility Agreement (FFA) as a subunit of the Steel Creek IOU.

Representatives from the United States Department of Energy, United States Environmental Protection Agency (USEPA), and South Carolina Department of Health and Environmental Control (SCDHEC) met on August 5, 2010, to discuss and evaluate the need for a remedial action regarding the ash overflow from P-Area Ash Basin operations into the surrounding downgradient area. The three agencies determined that there was not enough information at the time to make a remedial decision or determine the best administrative approach for the additional ash contamination. The newly discovered ash overflow area was identified as the WADB and administratively assigned to the Steel Creek IOU for further evaluation.

Soil, ash, and surface water samples were collected in 2010. A Sampling and Analysis Plan was developed in 2011 to address data gaps identified in the original dataset. Both datasets were used in the subsequent baseline risk assessment (BRA). The results of the subsequent BRA indicate that a potential risk to human receptors exceeds 1E-06 for exposure to arsenic, cesium-137(+D) and coal-related radionuclides. A summary of the refined constituents of concern (COC) for the WADB is provided in Section 1. There is no principal threat source material (PTSM), ecological, contaminant migration, or groundwater refined constituents of concern resulting from the ash.

Potential remedial alternatives have been developed to address the ash plume at the WADB. In accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), a range of diverse alternatives are used to compare during the detailed analysis. The range of alternatives includes options that 1) reduce the contaminant volume and need for long-term management, or 2) limit future exposure to contaminated media.

The RAO for the WADB is to:

- Prevent the IOU on-site worker from exposure to contaminants in surface/ash soil at concentrations exceeding 1E-06 risk or SRS background concentrations.

After screening, the retained general response actions and treatment technologies were combined to develop the remedial alternatives. Each of the remedial alternatives, with the exception of the No Action alternative, can attain the RAO either individually or in combination.

Based upon the technology screening and the RAO for the WADB, three remedial alternatives including four sub-alternatives are being carried forward for detailed alternatives analysis. All alternatives except the No Action alternative can attain the RAO. Alternatives A-2, A-3a, and A-3b will be combined with land use controls (LUCs).

Alternatives A-3c, and A-3d, which evaluate excavation of the total volume of ash, achieve unrestricted land use. The retained alternatives will be evaluated against the nine CERCLA criteria listed in the NCP, commonly called the National Contingency Plan. The comparative analysis presented in this document does not propose a preferred alternative. Rather, the preferred alternative will be presented in the Statement of Basis/Proposed Plan (SB/PP) document to be submitted after approval of this Focused CMS/FS.

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LIST OF ABBREVIATIONS AND ACRONYMS

ac	acre
ARAR	applicable or relevant and appropriate requirement
CAB	Citizens Advisory Board
CBCU	Crouch Branch Confining Unit
CCP	coal combustion product
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	curies
CM	contaminant migration
CMI/RAIP	Corrective Measures Implementation/Remedial Action Implementation Plan
CMS	Corrective Measures Study
COC	constituent of concern
CSM	conceptual site model
CWA	Clean Water Act
DUR	Data Usability Report
ERA	ecological risk assessment
FCMS/FS	Focused Corrective Measures Study/Feasibility Study
FFA	Federal Facility Agreement
FS	Feasibility Study
ft	feet / foot
GA	Gordon Aquifer
GCU	Gordon Confining Unit
GW	groundwater
ha	hectare
HH	human health
HHRA	human health risk assessment
HI	hazard index
IOU	Integrator Operable Unit
LAZ	Lower Aquifer Zone
LLAZ	Lower Lower Aquifer Zone
LUC	land use control
LUCIP	Land Use Control Implementation Plan
MCLAZ	Middle Clay Lower Aquifer Zone
mi	mile
mi^2	square mile
msl	mean sea level
NCP	National Oil and Hazardous Substances Contingency Plan
NPL	CERCLA National Priorities List
NRIE	Natural Resource Injury Evaluation
O&M	operations and maintenance
OU	operable unit

LIST OF ABBREVIATIONS AND ACRONYMS *(Continued/End)*

PAB	P-Area Ash Basin
PAOU	P-Area Operable Unit
pCi/g	picocuries per gram
PP	Proposed Plan
PRG	Preliminary Remediation Goal
PTSM	principal threat source material
RAO	remedial action objective
RCOC	refined constituent of concern
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RG	remedial goal
RGO	remedial goal objective
RI	Remedial Investigation
ROD	Record of Decision
RSL	Regional Screening Level
SAP	sampling analysis plan
SARA	Superfund Amendments and Reauthorization Act
SB/PP	Statement of Basis/Proposed Plan
SCDHEC	South Carolina Department of Health and Environmental Control
SITE	Superfund Innovative Technology Evaluation
SREL	Savannah River Ecology Laboratory
SRNS	Savannah River Nuclear Solutions, LLC
SRS	Savannah River Site
TBC	to-be-considered
TCCZ	Tan Clay Confining Zone
TCR	total cumulative risk
TES	Threatened, Endangered and Sensitive
TZ	Transmissive Zone
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
UTRA	Upper Three Runs Aquifer
WADB	Wetland Area at Dunbarton Bay
WSRC	Washington Savannah River Company, LLC

1.0 INTRODUCTION

This document is a Focused Corrective Measures Study/Feasibility Study (FCMS/FS) which discusses remedial action objectives (RAOs) and remedial goal options (RGOs) for the Wetland Area at Dunbarton Bay (WADB) (Figure 1-1) in support of the Steel Creek Integrator Operable Unit (IOU). The goals of the remedial actions are to protect human health and the environment and to mitigate the effects of contamination. The United States Environmental Protection Agency (USEPA) has established a structured process to identify and evaluate technologies for remedial applications. This process involves developing and screening a range of appropriate remedial options and selecting the most suitable approach(es) for corrective measures and remedial actions.

1.1 Purpose and Organization of Report

The purpose of this FCMS/FS is to assess the unit-specific alternatives for remedial action of the (WADB) subunit, which was added to the Federal Facility Agreement (FFA) as part of the Steel Creek IOU. This subunit was listed as part of the Steel Creek IOU because it represents a pathway for the release of contaminants which can impact human health and the environment. The area of concern is downgradient of the P-Area Ash Basin (PAB), where ash disposal activities have encroached towards and within the WADB. Characterization of the area has been conducted to further refine the impact of ash on soils, groundwater (GW), human and ecological receptors, and contaminant migration potential to GW. The evaluation presented in the appendices also supports the development of remedial actions in this FCMS/FS.

This FCMS/FS was developed in accordance with Comprehensive Environmental Compensation, and Liability Act (CERCLA) guidance. The general approach to evaluating potential remedial actions in the FCMS/FS is based on United States Department of Energy (USDOE) guidance, USEPA guidance, and Core Team agreements. The Core Team are representatives from the USDOE, USEPA, and South

Carolina Department of Health and Environmental Control (SCDHEC) who are the remedial decision makers for the project.

The FCMS/FS provides discussion to:

- Summarize results of the ash characterization
- Determine the RAOs for the media of interest
- Identify general response actions for the media of concern
- Identify remedial technologies that are applicable to the WADB
- Identify remedial alternatives that meet the RAOs
- Conduct a detailed analysis of remedial alternatives based on National Oil and Hazardous Substances Contingency Plan (NCP) criteria
- Conduct a comparative analysis of these remedial alternatives

The terms "corrective measures" and "remedial actions" are terms used under the Resource Conservation and Recovery Act (RCRA) and CERCLA to refer to potential cleanup activities. Although a comparative analysis of the corrective measures/remedial action alternatives is presented in this FCMS/FS, a preferred alternative is not proposed. The preferred alternative for the WADB will be presented in the Statement of Basis/Proposed Plan (SB/PP) to be submitted after approval of this FCMS/FS.

Supporting information includes the following: data tables (Appendix A); human health risk assessment (HHRA) / principal threat source material (PTSM) evaluation (Appendix B); ecological risk assessment (ERA) (Appendix C); contaminant migration (CM) analysis / groundwater monitoring results (Appendix D); RGO calculations (Appendix E), detailed cost estimates (Appendix F), and a Natural Resource Injury Evaluation (Appendix G) are provided as separate appendices and are pertinent to supporting the conclusions presented in this document.

1.2 Background Information

SRS, which comprises an area of approximately 803 square kilometers (km^2, 310 square miles [mi^2]), is located in Aiken, Barnwell, and Allendale counties about 32 km (20 miles [mi]) south of Aiken, South Carolina (Figure 1-1). USDOE owns SRS; Savannah River Nuclear Services, LLC, (SRNS) provides management and operating services. Since its creation in 1951, SRS has historically produced tritium, plutonium, and other special nuclear materials for national defense. SRS has also provided nuclear materials for the space program and for medical, industrial, and research efforts. Chemical and radioactive wastes are byproducts of the nuclear material production processes. Hazardous substances as defined by CERCLA and hazardous waste as defined by RCRA (40 Code of Federal Regulations [CFR] 261.20) are currently present in the environment at SRS.

On December 21, 1989, SRS was placed on the CERCLA National Priority List (NPL). In accordance with Section 120 of CERCLA, USDOE has entered into a FFA with SCDHEC and USEPA to coordinate cleanup activities at SRS under one comprehensive strategy that fulfills RCRA and CERCLA assessment, investigation, and response action requirements. The WADB is listed as a RCRA/CERCLA unit in Appendix C of the FFA as a subunit of the Steel Creek IOU.

The Core Team met on August 5, 2010, to discuss and evaluate the need for a remedial action regarding the ash overflow from P-Area Ash Basin (PAB) operations into the WADB (Figures 1-2 and 1-3). The newly discovered ash overflow area in and around Dunbarton Bay was administratively assigned to the Steel Creek IOU in the SRS FFA for further evaluation.

1.2.1 Unit Description

The dominant feature of the WADB is the Carolina bay called Dunbarton Bay (Figure 1-2). Carolina bays are shallow elliptical depressions that vary in size, are oriented northwest to southeast, are commonly 0.6- to 1.2-m (2- to 4-feet [ft]) deep, and are found on the southeastern Atlantic coastal plain area. Their widespread extent was unknown until the use of aerial photography in the 1930s at Myrtle Beach, South Carolina.

The most widely accepted theory of Carolina bay formation is that originally there were shallow depressions in the landscape with an aquitard underneath that allowed precipitation to perch above the aquitard surface. Prevailing winds then shaped the depressions into the now familiar elliptical shape. The cause of the original depression, however, is still unknown.

Carolina bays contain soils that are dark in color and can range in texture from sandy loam to a silty clay loam. Carolina bays have high levels of organic matter and often have thick layers of black humus and peat including decayed vegetation and the presence of illite and kaolinite clays in the depression bottom. Peat and organic soil layers can vary in thickness to over 3.7 m (12 ft) depending upon the age of the bay. The bays tend to have high amounts of organic carbon providing high levels of organic acids, high cation exchange capacity, low hydraulic conductivity, and low base saturation.

Carolina bays, in general, have a history of disturbance. Ditching and draining was a common practice, primarily to support cultivation. Bays on the SRS have been protected from such disturbances since 1951, and some bays on the SRS have been restored to pre-disturbance conditions. The Dunbarton Bay has been identified as a designated wetland at the WADB subunit.

Habitats and Ecological Setting

The diverse habitats of SRS support a wide range of aquatic, semi-aquatic, and terrestrial species. The WADB is comprised of both cypress and hardwood canopy habitats. The area is predominantly flat containing disturbed and undisturbed upland areas that grades into a depositional wetland. Three habitat types exist within the survey area; these include: 1) 3.0 hectares (ha, 7.5 acres [ac]) of disturbed and undisturbed portions of a maturing pine and mixed pine hardwood upland and mesic forest; 2) 0.8 ha (2.0 ac) of upland early successional vegetation along roadside and utility corridor rights-of-ways; and 3) approximately 12 ha (30.5 ac) of disturbed (overburden of ash deposition) and undisturbed portions of a maturing mixed bottomland and cypress swamp forests. Botanical and wildlife surveys did not identify any critical habitat nor locate any threatened, endangered and sensitive (TES) species within the project area.

Groundwater Hydrogeology

The unconsolidated marine and fluvial sediments of the Atlantic coastal plain underlying P Area and all of SRS are a variably stratified, heterogeneous sequence of sand, clay, limestone, and gravel layers. In terms of hydrostratigraphy, the uppermost sediments compose the Floridian Aquifer System. In P Area, the Floridian Aquifer System consists of, in ascending order, the Gordon Aquifer (GA), the Gordon Confining Unit (GCU), and the Upper Three Runs Aquifer (UTRA). Any groundwater contaminant plume from ash would be located in the UTRA of the Floridian Aquifer System. The Floridian Aquifer System is separated from lower aquifer units by the Crouch Branch Confining Unit (CBCU), which is a competent aquitard. A generalized local correlation for the WADB between lithostratigraphic and hydrostratigraphic units is provided in in Figure 1-4.

The GA consists of the sandy section of the Snapp Formation and the overlying Fourmile and Congaree Formations. The average thickness of the aquifer is approximately 29 m (96 ft) within the area of interest and consists of unconsolidated sand with several pebbly zones.

The GCU separates the GA from the UTRA. The GCU is made up of fine-grained sand, glauconitic sand, clay of the Warley Hill Formation (green clay), and clayey limestone of the Santee Formation. The average thickness of the aquitard is approximately 5 m (16 ft) in the area. The hydraulic head below the GCU in P Area is approximately 6 m (20 ft) lower than the hydraulic head above the GCU. This large head difference is evidence of the low permeability of the confining unit.

The UTRA extends from the GCU to the water table. The thickness of this aquifer is typically 150-ft thick and is informally divided into three major aquifer zones: the Lower Aquifer Zone (LAZ), the Transmissive Zone (TZ), and the combined “A” and “AA” horizons (A/AA) (Figures 1-5 and 1-6). Sediments from the Santee Formation to the base of the Dry Branch Formation make up the LAZ. The average thickness of the LAZ is approximately 26-m (85-ft) thick. There can also be other less significant aquifer zones including the Middle Clay Lower Aquifer Zone (MCLAZ) and the Lower Lower Aquifer Zone (LLAZ) differentiated in the LAZ depending upon the history of local deposition.

Between the LAZ and the TZ lays the Tan Clay Confining Zone (TCCZ). The TCCZ is made up of sediments from the Dry Branch Formation and contains tan to orange clay and sandy clay interbedded with clayey sand and sand.

The TZ lies atop the TCCZ and the A/AA lies atop the TZ. The TZ is the upper portion of the Dry Branch and the average thickness is approximately 9 m (31 ft). The sediments are moderately to poorly sorted, coarse to medium grained silty sands, with sandy and silty clay layers and some pebble zones. The A/AA horizons consist of all sediments above the Dry Branch Formation, including the Tobacco Road Formation and the “upland” unit. The “upland unit” sediments are commonly very dense and clayey and often contain gravely sand. The topographic surface bounds the top of the A/AA creating a widely variable thickness across the study area. It is deeply incised by the lower portions of stream channels such as Steel Creek and Meyers Branch.

Surface Topography

The base floor of the area lies almost entirely at 75 m (246 ft) above mean sea level (msl). Steep ridgelines up to 89 m (292 ft) above msl border portions and have subjected it to fluvial forces, effects of which have been amplified by stormwater runoff from industrial areas. In its entirety, Dunbarton Bay is part of a complex of three bays (Bay 96, 97 and 98) thought to originally exist as a single bay. Historically, the bays that comprise the Dunbarton Bay complex were segregated by roads and a rail transportation line altering the bay system. Bay 96 is the present day bay that is located downgradient of the PAB. Bay 96 is referred to herein as Dunbarton Bay. Dunbarton Bay is flanked by Bay 98 on the east and Bay 100 on the west (Figure 1-2).

Surface water is only intermittently present in the WADB. It was only possible to obtain one surface water sample directly in the Dunbarton Bay, which was collected prior to development of the sampling and analysis plan (SAP), and it was collected from a low spot in the middle of the bay. There was no surface water in the WADB in 2011. This indicates the surrounding area and Dunbarton Bay is not hydraulically connected to the aquifer at this time, if at all. The cycle of the Dunbarton Bay appears to be precipitation – evapotranspiration driven. As the precipitation rate exceeds the hydraulic conductivity of the sediment in the bottom of the depressions, the water level in the surrounding area and Dunbarton Bay will increase. As the precipitation rate decreases and evapotranspiration dominates the cycle, water levels in the entire area will decrease or evaporate completely as it is now.

Dunbarton Bay is hydraulically isolated at this point in time from the water table aquifer. The potentiometric surface averaged 70 m (230 ft) above msl beneath Dunbarton Bay and the lowest spot which could be located in the wetland measured 73 m (238 ft) above msl (the low spot) creating a minimum vadose zone thickness at least 2 m (8 ft) (Figures 1-5 and 1-6).

The volume of water which can be retained in the area is also limited. Ditches were constructed in the area to carry storm water runoff from Dunbarton Bay to Meyers Branch. It is apparent on the topographical relief map (see Figure 1-7) the Dunbarton Bay as well as other Carolina bays in the area have drainage provided by a manmade ditch system for minimizing accumulations of precipitation in these areas. As a result, the area can only reach a water level potential equal to the maximum depth of the ditching system elevation. This area has a long history of disturbance and fragmentation by pre-SRS roads, making the natural drainage flows challenging to interpret. Based on historical aerial photographs, vegetated riparian zones connect the area to the head waters of Meyers Branch, as part of the larger Dunbarton Bay system.

The ash flow from the PAB area follows a natural surface elevation gradient to Dunbarton Bay. The ash has been transported from the PAB area and has been distributed at various depths along a distance of approximately 762 m (2,500 ft) extending south into the Dunbarton Bay itself. The Dunbarton Bay is the only designated wetland where the ash flow has encroached.

1.2.2 Unit History

SRS began early infrastructure development between 1951 and 1955 including the construction of P-Reactor which operated between 1954 and 1991. Similar to each reactor area at SRS, P Area utilized a coal-fired powerhouse to generate steam and electricity, with coal ash (coal combustion products [CCP]) produced as a result of boiler operations. In P Area, this ash was mixed with water and transferred to the PAB via a sluice line. In 2010, during clearing of 14 ha (35 ac) surrounding the PAB, ash was discovered outside the ash basin to the north and south-southwest. Additional characterization efforts established that the ash deposition extended to what was thought to be another 19 ha (47 ac) to the south-southwest into the Dunbarton Bay.

This information was presented to the Core Team on June 15, 2010, and again on August 5, 2010. The administrative path forward was discussed at the August 5th meeting and the Core Team concluded there was not enough information at the time to make a remedial decision or determine the best administrative approach for the additional ash.

The Core Team agreed to the following path:

- Provide a schedule for additional surface water and groundwater (GW) characterization
- Develop a SAP to include the following:
    - Shallow GW sampling

- Surface water samples at Myers Branch
- GW sampling from an existing well cluster near Dunbarton Bay

- Execute the characterization plan and evaluate results
- Develop a Scoping Summary and reconvene the Core Team to discuss results and appropriate administrative and remedial path forward.

Subsequent to these decisions, a SAP (SRNS 2011) was prepared to support additional surface water and groundwater sampling. During execution of the SAP in 2011, no surface water samples were collected in Dunbarton Bay because there was no surface water present in the wetlands during characterization activities. There is currently no surface water in the wetlands. It should be noted that two surface water samples were collected in 2010 prior to development of the SAP; one directly in a low spot of the Carolina Bay and the other in a downgradient drainage feature. The analytical results of these two surface water samples are used as data sources in this FCMS/FS. Ten (10) ash/soil samples were collected and analyzed in 2011 for ecological assessment by the Savannah River Ecology Laboratory. At least two events of groundwater sampling from each of the thirteen (13) monitoring wells were collected. Various biota samples were also collected. Therefore, all sampling of media included in the SAP, with the exception of surface water sampling, was completed. See Figures 1-8 through 1-10 for sample locations.

Conceptual Site Model

The conceptual site model (CSM) is an objective framework for assessing data pertinent to the investigation. The CSM identifies and evaluates suspected sources of contamination, contaminant release mechanisms, potentially affected media (secondary sources of contamination), potential exposure pathways, and potential human and ecological receptors.

Exposure pathways describe the course a chemical or physical agent takes from the source to the exposed receptor. The following five (5) components make up an exposure pathway:

- Source (facility operations, spill, etc.)
- Exposure media (soil, groundwater, etc.)
- Exposure point (drinking water well, etc.)
- Exposure route (external radiation, ingestion, dermal contact, inhalation, etc.)
- Receptor (resident, worker, wildlife, etc.)

If any of these elements is missing, the pathway is incomplete and is not considered further in the quantitative risk assessment. A pathway is complete when all five components are present to permit potential exposure of a receptor to a source of contamination. Exposure analysis is conceptually important in terms of identifying all potentially complete exposure routes, understanding the nature and extent (as well as fate and transport) of contamination, and developing preliminary remedial alternatives. In a complete pathway, exposure occurs at exposure points that may represent only a small portion of the entire exposure route. If there is no exposure point, then there is no exposure, and the pathway is considered incomplete. In general, the primary sources of contamination at the WADB resulted from the movement of ash from the PAB area.

The area in question is located in a remote part of SRS and it is not within any administrative or industrial areas that are currently designated for industrial land use. The environmental setting precludes any residential (unrestricted) or industrial land use in the future. Therefore, the most likely receptor scenario is an onsite worker (i.e., a worker who is conducting research, collecting samples, performing maintenance, etc.). However, in order to support risk management decision making, a variety of hypothetical receptors are evaluated in the HHRA. These include the standard (i.e., default) unrestricted (i.e., residential) and industrial land use scenarios as well as the site-specific onsite worker and adolescent trespasser scenarios.

The primary exposure pathways for evaluation relative to human receptors include:

- Exposure to surface media 0 to 0.3 meters (m) (0 to 1 ft) via incidental ingestion, dermal contact, inhalation of windblown dust, inhalation of volatile constituents, and external exposure from radionuclides.
- Exposure to surface water via ingestion, inhalation, dermal contact and external exposure from radionuclides (conservative drinking water comparison only).
- Exposure to groundwater through ingestion of drinking water from contaminated sources (drinking water comparison).

From an ecological risk perspective, the habitat at Dunbarton Bay likely supports both terrestrial and aquatic/semi-aquatic receptors to some degree. The media of concern are primarily the surficial ash 0 to 0.3 m (0 to 1 ft) and surface water. Terrestrial receptors include earthworm (soil invertebrate), old-field mouse (herbivorous mammal), short-tailed shrew (insectivorous mammal), raccoon (omnivorous mammal), American robin (insectivorous bird) and red-tailed hawk (carnivorous bird). Aquatic/semi-aquatic receptors include aquatic organisms, benthic (sediment) dwelling organisms, raccoon (mammalian aquatic predator) and green heron (avian aquatic predator).

Leaching of contaminants from the contaminated media to groundwater constitutes a secondary contaminant release mechanism. The potential to leach to groundwater is evaluated in the contaminant migration analysis.

The preliminary CSM for the WADB is presented in Figure 1-11.

1.3 Data Evaluation

There are two datasets associated with the soil/ash characterization of Dunbarton Bay. The first dataset consisted of ten soil/ash sample locations (PAB-116, -117, -119, -120, -153, -182, -183, -301, -302, -304) within Dunbarton Bay from the 0- to 0.3-m (0- to 1-ft) ash/soil interval (Figure 1-8). Two surface water samples (PAB-428 and PAB-429) (Figure 1-9), and 13 groundwater wells were also sampled (Figure 1-10). This data was collected in June 2010 and analyzed by General Engineering Laboratory. The data was verified and validated (V&V) and was used in a preliminary risk evaluation that was presented to the Core Team in August 2012 to assist in the determination of the administrative path forward for this area. This dataset has since been upgraded to definitive level data and is presented in the Data Usability Report (DUR) for this project (Appendix A).

A SAP was developed in 2011 to address data gaps identified in the original dataset (SRNS, 2011). These data gaps pertained primarily to the ecological risk assessment. More specifically, site specific biological field studies were initiated for metals associated with the ash media. The studies targeted both biotic (i.e., fauna) and abiotic (i.e., ash/soil) media. Although surface water was also intended to be sampled, Dunbarton Bay was dry due to regional drought conditions and no surface water samples were obtained. The Savannah River Ecology Laboratory (SREL) collected and analyzed the ash/soil and biota samples in 2011/2012. The data quality for this dataset is unverified and unvalidated (U&U).

In addition, four monitoring wells were installed to address the data uncertainty associated with the groundwater media and to determine if there is a threat of groundwater contamination migrating from Dunbarton Bay into other areas of SRS or off-site. The groundwater data is definitive level and is assessed in the DUR.

The data used for the HHRA/PTSM evaluation, ERA, and CM and groundwater evaluation is summarized in Table 1-1.

1.3.1 Nature and Extent of Contamination

The ash deposition area has been determined to begin on the south side of the PAB and extend in a southerly direction for approximately 762 m (2,500 ft) into the Dunbarton Bay. The maximum width at the leading edge of the ash deposition area is ~300 m (~985 ft). The depth of ash deposition is variable and is less than 0.3 to 0.9 m (1 to 3 ft) in thickness (see Figure 1-3).

The area of ash deposition is approximately 15 ha (37 ac). There is a total volume of 61,332 cubic meters (m^3, ~80,220 cubic yards [yd^3]) of ash.

Summary of the Human Health Risk Assessment

The HHRA is presented in Appendix B of this document. The results indicate that the potential risk to all four human receptor scenarios evaluated in the HHRA exceeds 1E-06 for exposure to arsenic, cesium-137(+D) and coal-related radionuclides. The risk estimates for each of the refined constituents of concern (RCOCs) for each receptor scenario are summarized below. RCOCs are defined as COCs that require a remedial action.

Residential scenario, 0-1 ft ash/soil interval: Human Health (HH) RCOCs include arsenic (risk = 5.5E-05), cesium-137(+D) (risk = 5.5E-05), potassium-40 (risk = 8.8E-05), radium-226(+D) (risk = 1.9E-04), and uranium-238(+D) (risk = 2.9E-06); the total cumulative risk is 3.9E-04.

Industrial worker scenario, 0- to 0.3-m (0- to 1-ft) ash/soil interval: HH RCOCs include arsenic (risk = 1.3E-05), cesium-137(+D) (risk = 3.3E-05), potassium-40 (risk = 5.0E-05), radium-226(+D) (risk = 1.1E-04), and uranium-238(+D) (risk = 1.4E-06); the total cumulative risk is 2.1E-04.

IOU Onsite worker scenario, 0- to 0.3-m (0- to 1-ft) ash/soil interval: HH RCOCs include arsenic (risk = 6.5E-06), cesium-137(+D) (risk = 1.7E-05), potassium-40 (risk = 2.4E-05), and radium-226(+D) (risk = 5.1E-05); the total cumulative risk is 9.9E-05.

Adolescent trespasser scenario, 0- to 0.3-m (0- to 1-ft) ash/soil interval: HH RCOCs include arsenic (risk = 3.0E-06), cesium-137(+D) (risk = 1.3E-05), potassium-40 (risk = 1.6E-05), and radium-226(+D) (risk = 3.5E-05); the total cumulative risk is 6.7E-05.

No constituents are identified as RCOCs for the surface water media.

Summary of the Principal Threat Source Material Evaluation

The PTSM evaluation is also presented in Appendix B. No PTSM RCOCs were identified for the ash/soil media at Dunbarton Bay (Hazard Index [HI] = 0.6; cumulative risk = 3.0E-04).

Summary of the Ecological Risk Assessment

The ecological risk assessment is presented in Appendix C of this document. It considers multiple lines-of-evidence to make a determination whether the ash (and surface water) media within Dunbarton Bay either has in the past or has the potential in the future to pose a significant risk to wildlife receptors. These lines-of-evidence include the following: chemical analysis of the impacted medium, literature-based risk calculations, bioaccumulation and field tissue surveys, trophic level modeling, population/community evaluations, and toxicity testing information.

There is no clear evidence that Dunbarton Bay is negatively impacting ecological receptors, as it appears that it is as healthy and diverse an ecosystem as similar areas adjacent to it that are not contaminated. The overall weight-of-evidence leads to the conclusion that the naturally occurring trace metals associated with the coal ash that is present within the Dunbarton Bay system do not pose an unacceptable risk to representative populations inhabiting or utilizing the area or to special species of concern. Therefore, no ecological RCOCs for either the ash/soil or surface water media are identified and there are no problems warranting action from an ecological risk perspective.

Summary of the Contaminant Migration Analysis/Groundwater Evaluation

The contaminant migration analysis is presented in Appendix D. There are no constituents that have the potential to migrate to the aquifer and exceed the maximum contaminant levels (MCL) (or regional screening levels [RSL]/Preliminary Remediation Goals [PRG] in the absence of a MCL) within 1,000 years. Therefore, no CM RCOCs are identified for the ash/soil media.

In addition, an evaluation of the groundwater medium is also presented in Appendix D of this document. Screening was conducted for all maximum detected groundwater concentrations and compared to either the MCLs or tap water RSLs. Groundwater samples were collected from various depths beneath the wetlands and Dunbarton Bay and only one detection of gross alpha and one detection of beryllium were found to exceed an MCL, one time each (Summary Table 1-2). The fact there were only two analytes to exceed a drinking water standard provides a converging line of evidence that a conservative contaminant migration analysis has accurately predicted that none of the soil analytes would migrate to groundwater and exceed an MCL, RSL, or PRG. A total of 13 monitoring wells were used to sample groundwater at various depths below the wetland and Dunbarton Bay. All wells were sampled at least two times from April 2011 until February 2012. Groundwater samples were collected from 2.7 m (9 ft) msl to 63 m (207 ft) msl beneath and near the Dunbarton Bay. The large number of samples collected provides for statistical stability and representiveness in monitoring trends of groundwater quality.

Gross alpha and beryllium were not considered groundwater RCOCs since both are anomalous detections from a single well - RGW-7C. Beryllium was detected once at 10.6 μg/L (MCL = 4.0 μg/L) in April 2011 but thereafter was only detected at less than 1.0 μg/L in June 2011, September 2011, November 2011, and February 2012 or 1 out of 5 times. Gross alpha was similarly detected once at 18.2 pCi/L (MCL = 15.0 pCi/L) in April 2011, but thereafter, was only detected at less than 2.7 pCi/L or not detected in the next four sampling events, or 1 out of 5 times. Therefore, there has only been one detection of each analyte above its respective drinking water standard, with four samples collected subsequently, without exceeding a drinking water standard. RGW-7C is side-gradient to the groundwater flow in the wetlands and the screen zone is too deep to be impacted by the wetlands. Deeper wells closer to the wetlands did not have these detections. Therefore, groundwater RCOCs have not been identified.

Conclusion

There is no PTSM, ecological, contaminant migration, or groundwater RCOCs identified for the WADB resulting from the ash. The potential risk to all four human receptor scenarios evaluated in the HHRA exceeds 1E-06 for exposure to arsenic, cesium-137(+D) and coal-related radionuclides. A summary of the refined constituents of concern for Dunbarton Bay is provided in Table 1-3. Based on these conclusions, the preliminary CSM has been revised and presented in Figure 1-12.

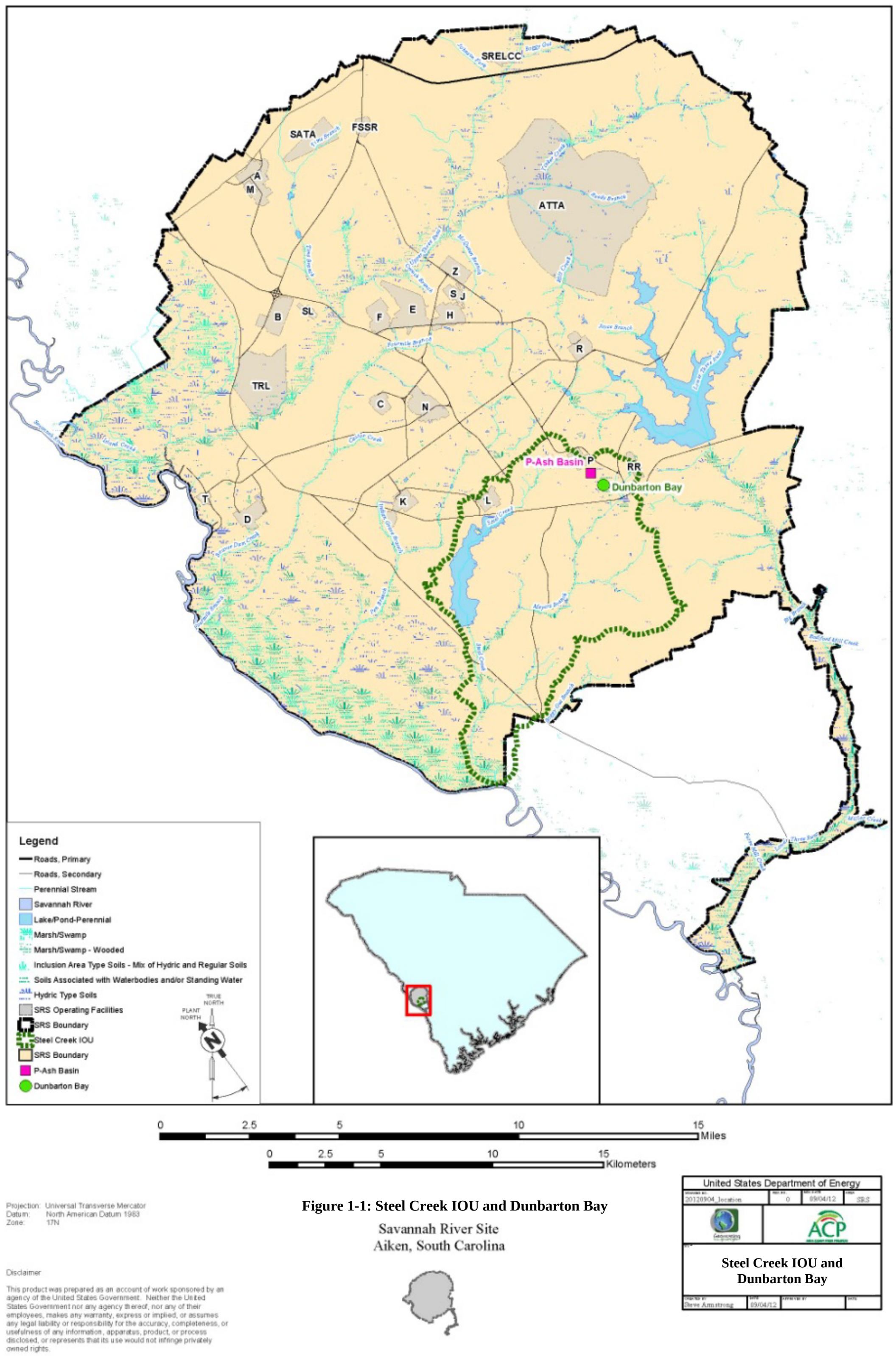


Figure 1-1. Steel Creek IOU and Dunbarton Bay

Figure 1-2. Layout of the Wetland Area at Dunbarton Bay Subunit with Other Carolina Bays

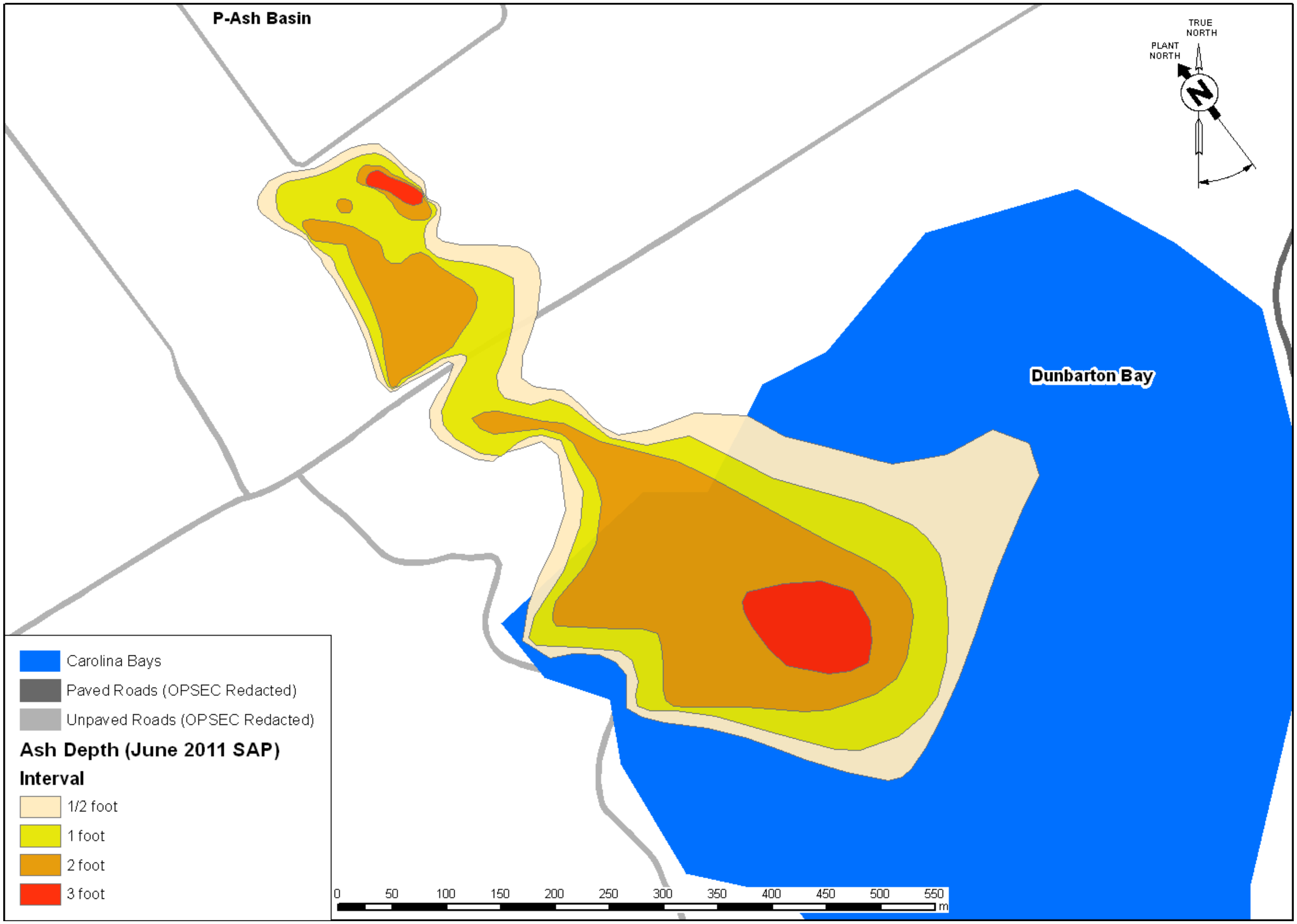


Figure 1-3. Ash Depth for the Wetland Area at Dunbarton Bay Subunit

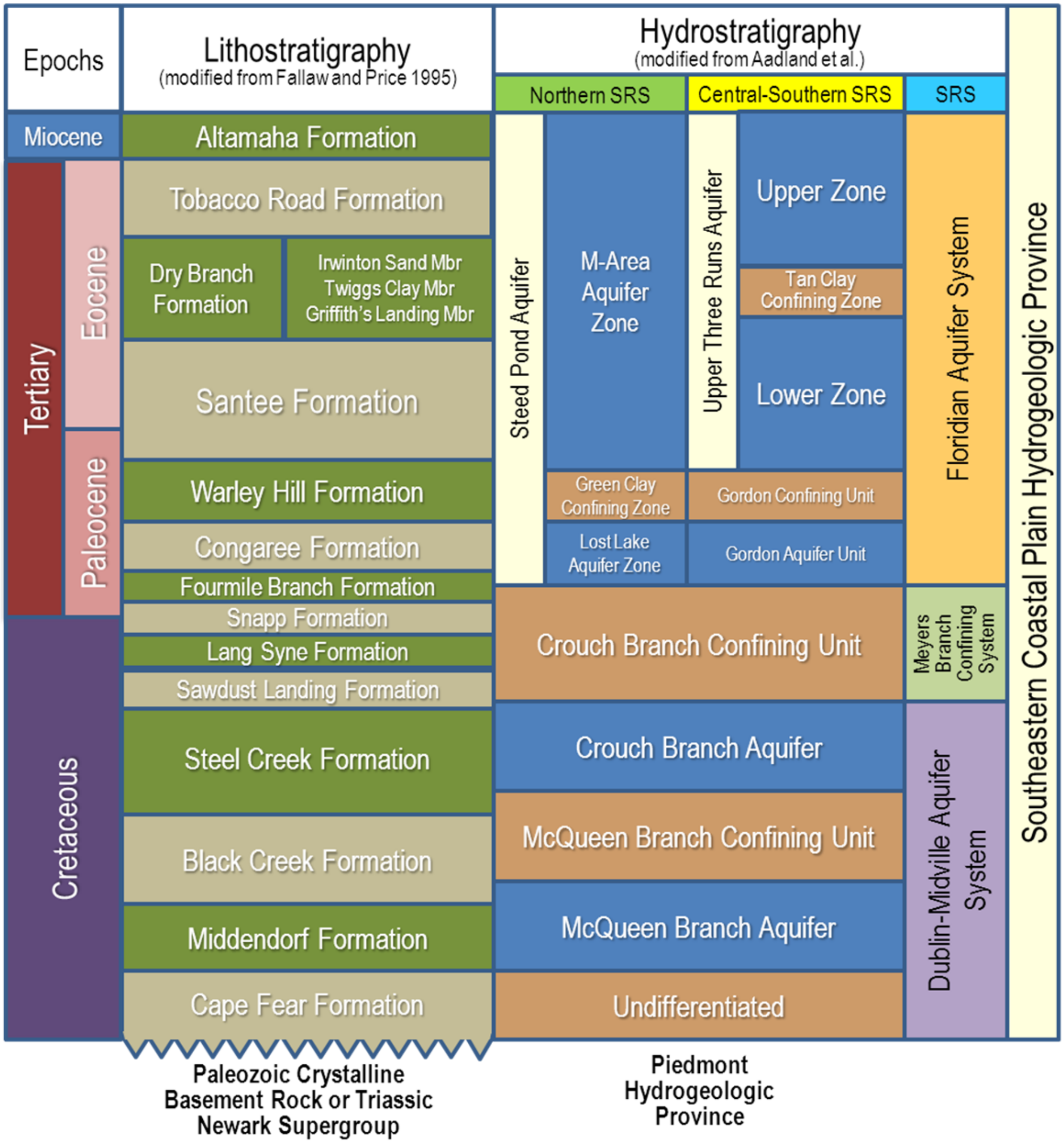


Figure 1-4. Lithostratigraphic and Hydrostratigraphic Unit Comparisons at the Wetland Area at Dunbarton Bay

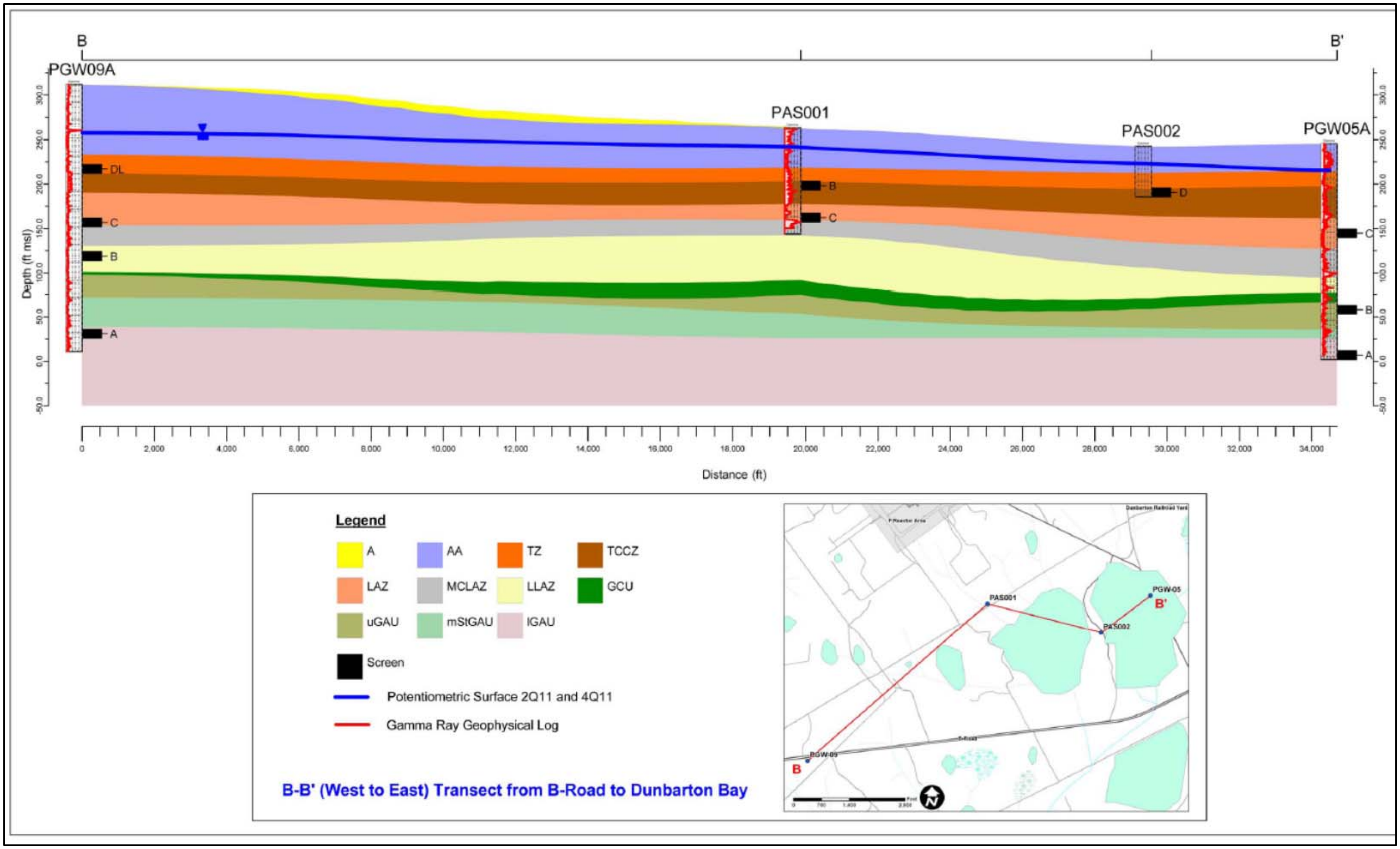


Figure 1-5. West to East Geological Cross Section of Wetland Area at Dunbarton Bay Subunit

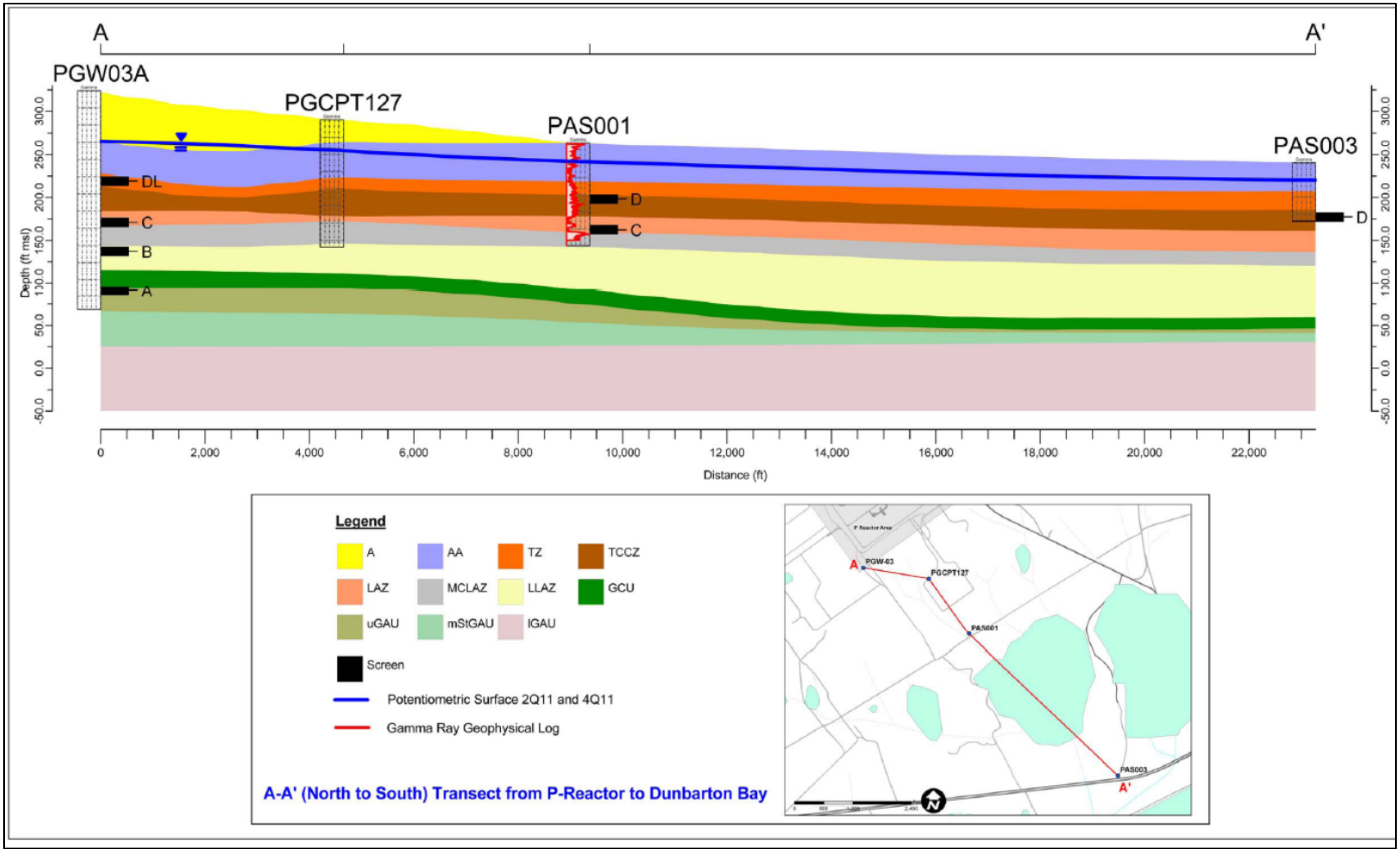


Figure 1-6. North to South Geological Cross Section of Wetland Area at Dunbarton Bay Subunit

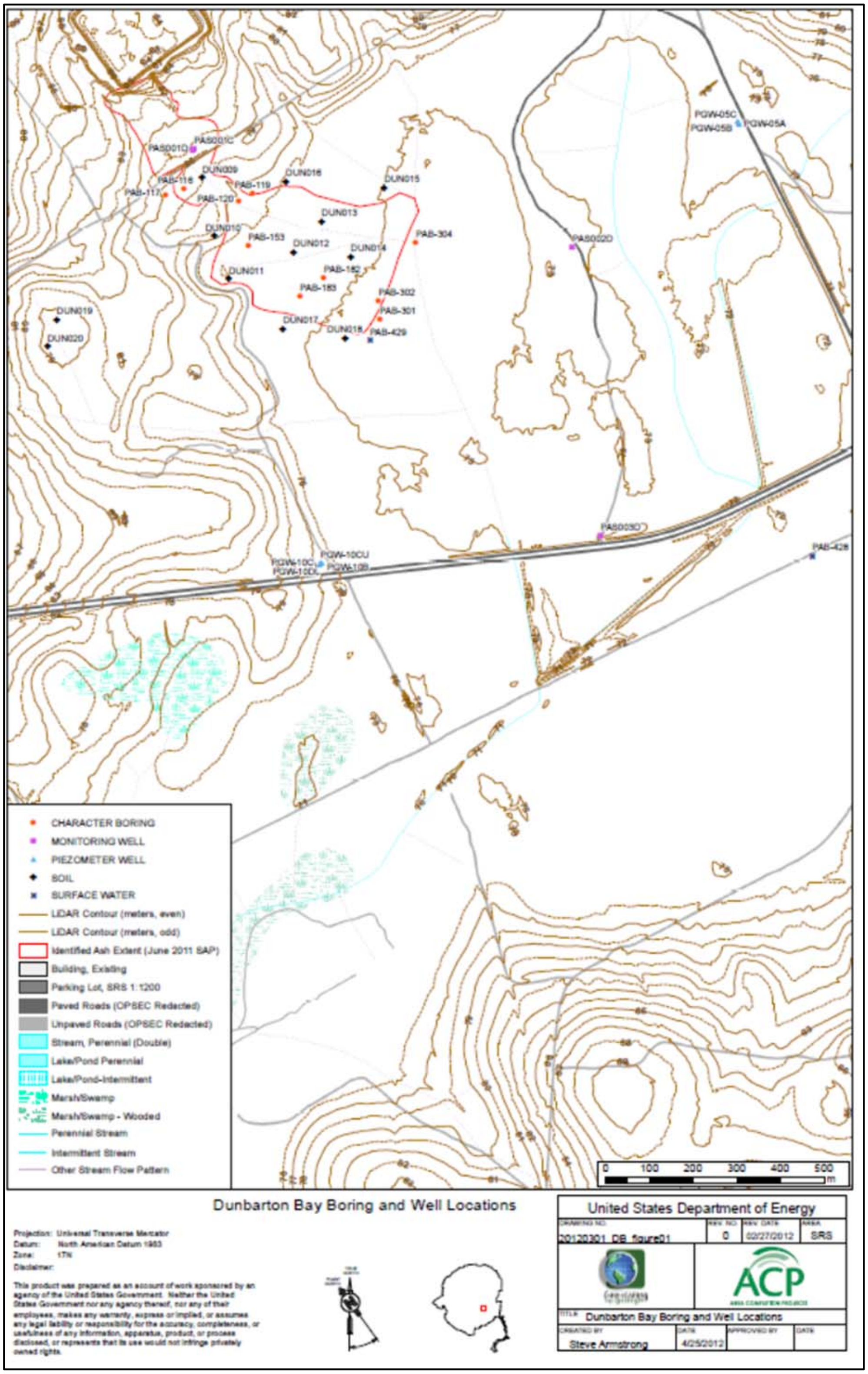


Figure 1-7. Topographic Map of Wetland Area at Dunbarton Subunit

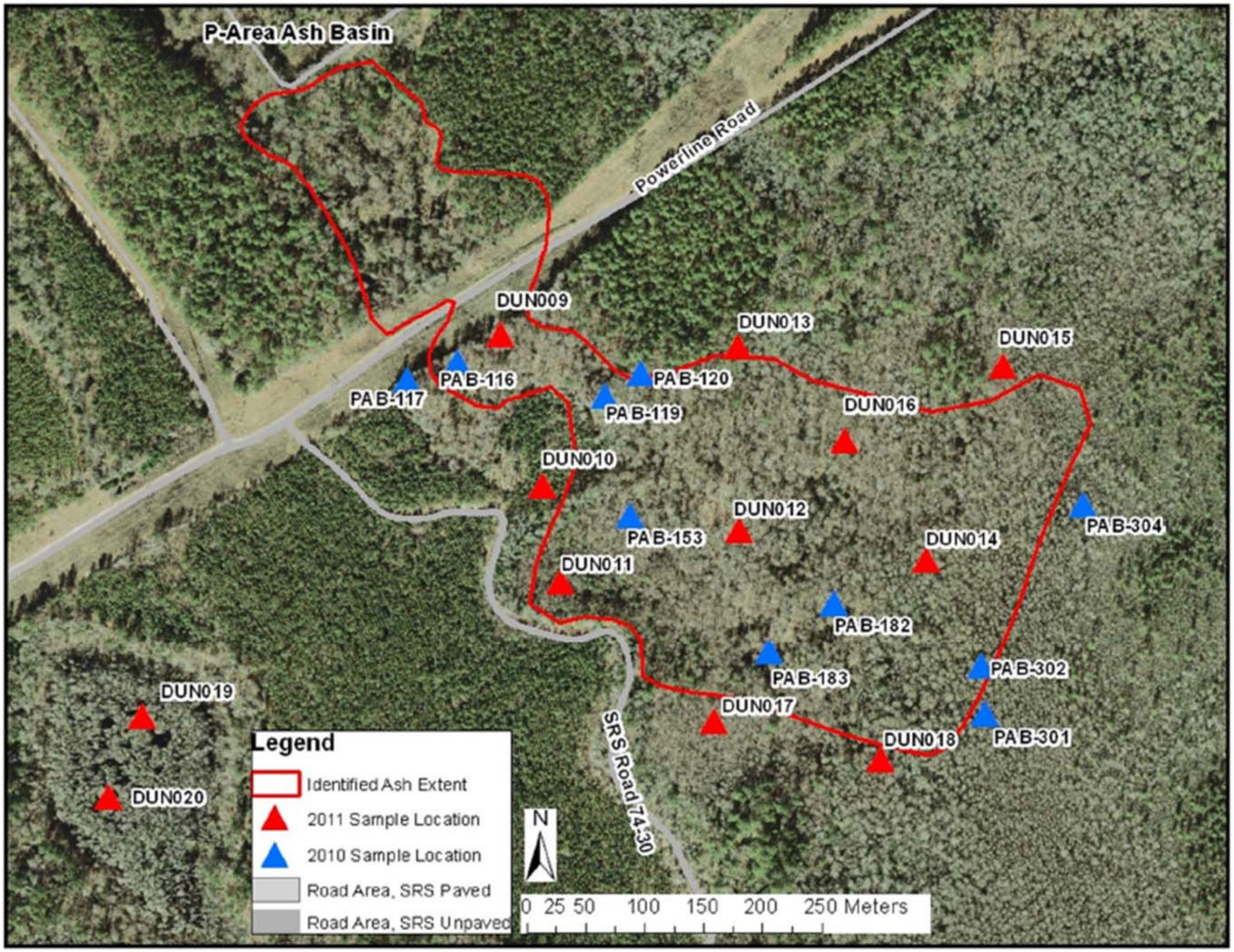
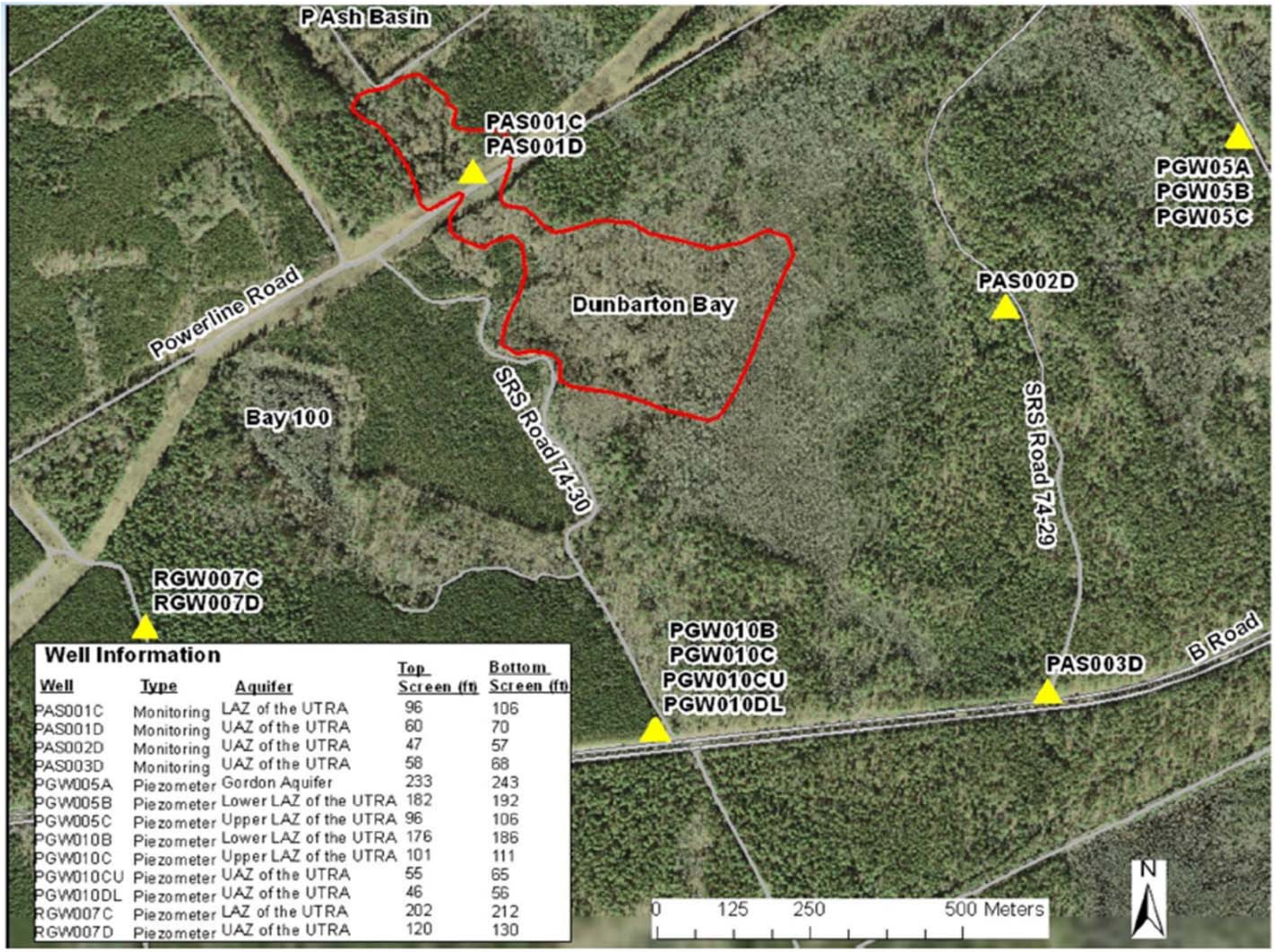


Figure 1-8. Soil Sampling Locations for Wetland Area at Dunbarton Bay Subunit

Figure 1-9. Surface Water Sample Locations from the Wetland Area at Dunbarton Bay Subunit



Well	Type	Aquifer	Top Screen (ft)	Bottom Screen (ft)
PAS001C	Monitoring	LAZ of the UTRA	96	106
PAS001D	Monitoring	UAZ of the UTRA	60	70
PAS002D	Monitoring	UAZ of the UTRA	47	57
PAS003D	Monitoring	UAZ of the UTRA	58	68
PGW005A	Piezometer	Gordon Aquifer	233	243
PGW005B	Piezometer	Lower LAZ of the UTRA	182	192
PGW005C	Piezometer	Upper LAZ of the UTRA	96	106
PGW010B	Piezometer	Lower LAZ of the UTRA	176	186
PGW010C	Piezometer	Upper LAZ of the UTRA	101	111
PGW010CU	Piezometer	UAZ of the UTRA	55	65
PGW010DL	Piezometer	UAZ of the UTRA	46	56
RGW007C	Piezometer	LAZ of the UTRA	202	212
RGW007D	Piezometer	UAZ of the UTRA	120	130

Figure 1-10. Groundwater Sampling Locations for the Wetlands at Dunbarton Bay Subunit

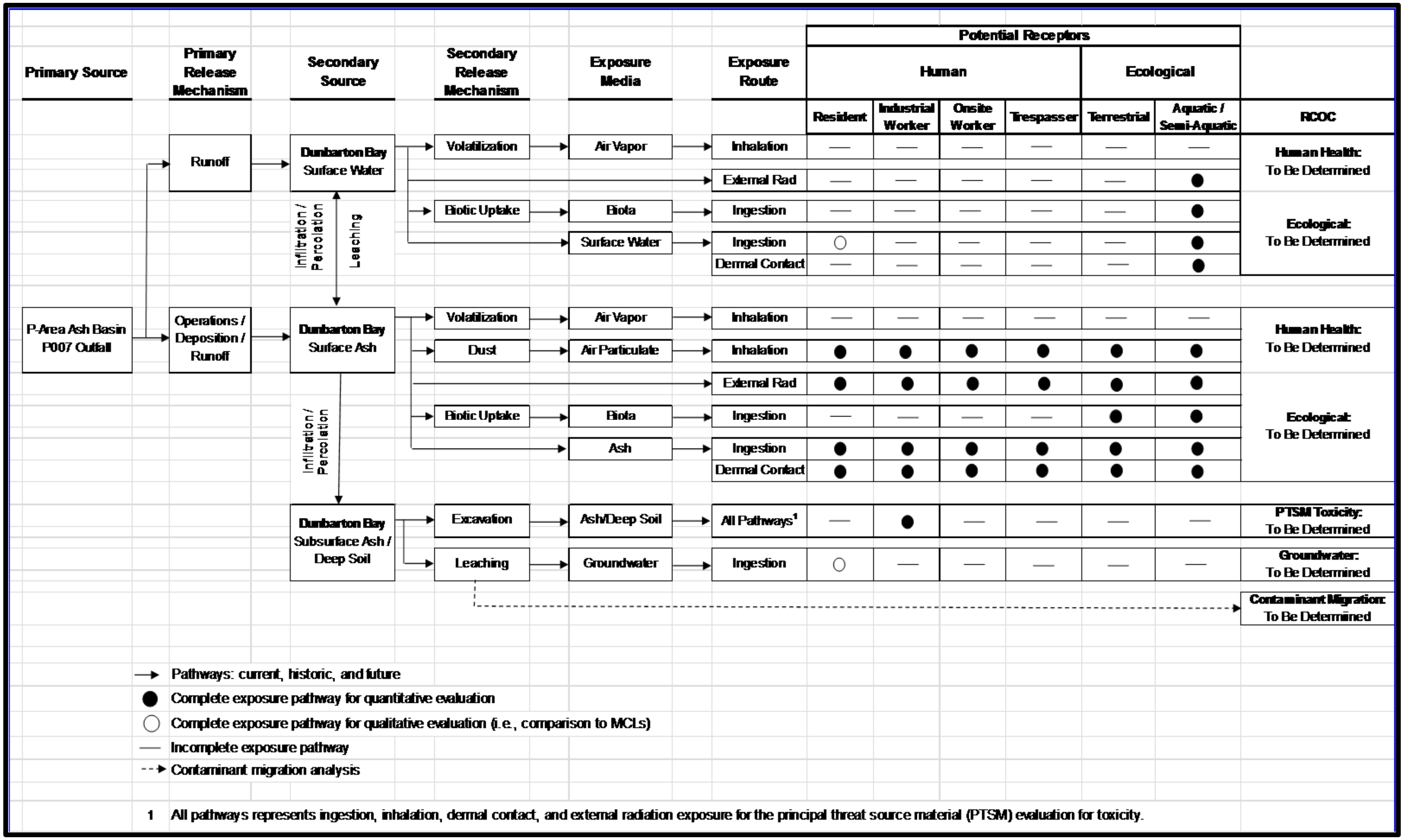
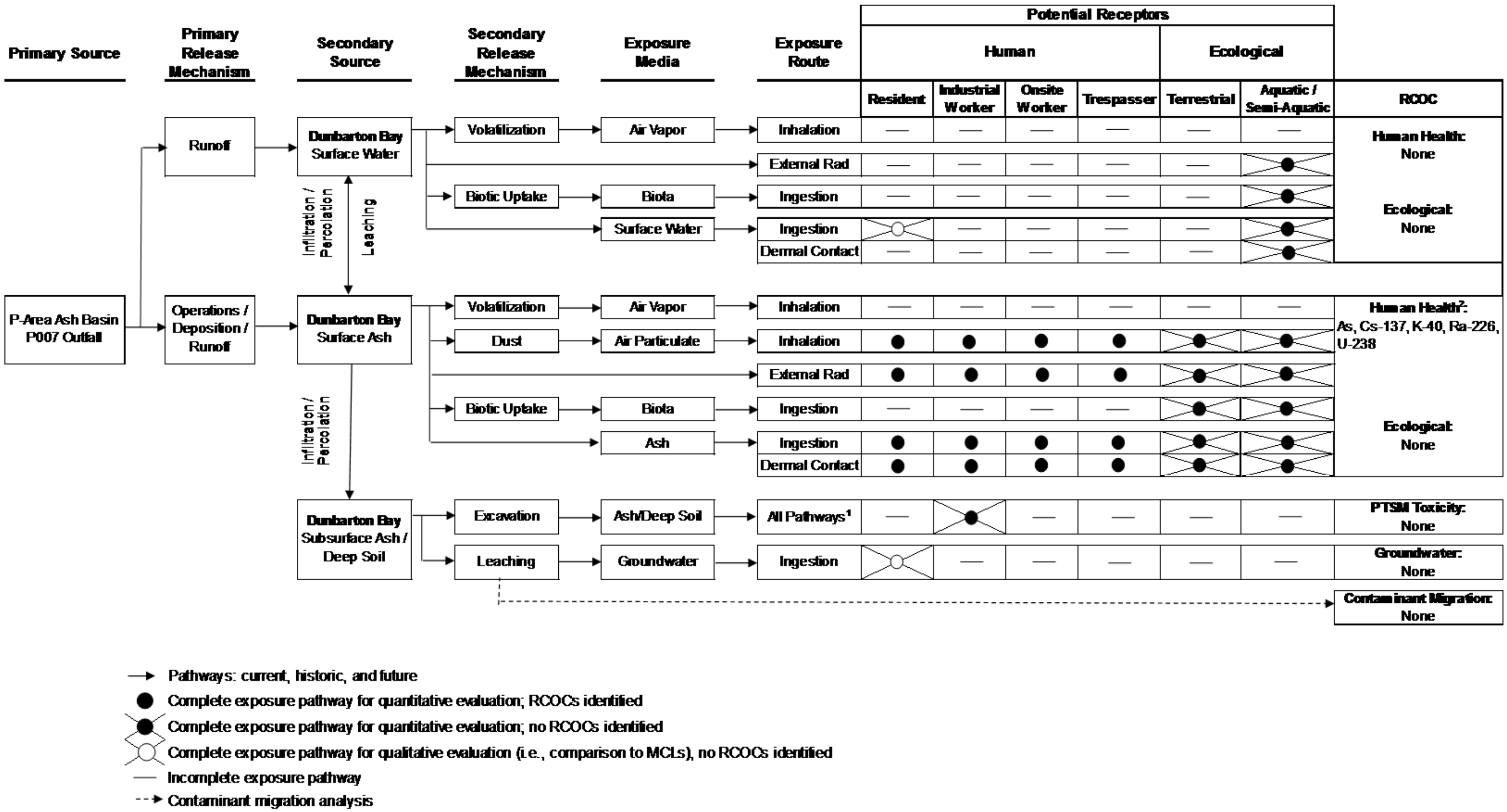


Figure 1-11. Preliminary Conceptual Site Model for the Wetland Area at Dunbarton Bay Subunit



1 All pathways represents ingestion, inhalation, dermal contact, and external radiation exposure for the principal threat source material (PTSM) evaluation for toxicity.

2 Resident RCOCs (risk) = As (5.5E-05), Cs-137(+D) (5.5E-05), K-40 (8.8E-05), Ra-226(+D) (1.9E-04), U-238(+D) (2.9E-06). Total cumulative risk (**TCR**) = **3.9E-04**
Industrial Worker RCOCs (risk) = As (1.3E-05), Cs-137(+D) (3.3E-05), K-40 (5.0E-05), Ra-226(+D) (1.1E-04), U-238(+D) (1.4E-06). **TCR = 2.1E-04**
Onsite Worker RCOCs (risk) = As (6.5E-06), Cs-137(+D) (1.7E-05), K-40 (2.4E-05), Ra-226(+D) (5.1E-05). **TCR = 9.9E-05**
Adolescent Trespasser RCOCs (risk) = As (3.0E-06), Cs-137(+D) (1.3E-05), K-40 (1.6E-05), Ra-226(+D) (3.5E-05). **TCR = 6.7E-05**

Figure 1-12 Revised Conceptual Site Model for the Wetland Area at Dunbarton Bay Subunit

Table 1-1. Data Used for Evaluation in the Focused CMS/FS

Sample ID Prefix	# Sample Locations	Analytes	Media	Data Quality Level	Data Use
PAB	10	TAL metals, Rads	Ash/soil	Definitive	Extent, HHRA, PTSM, ERA, CM
DUN	10 – Dunbarton Bay 2 (Bkgrd) - Bay 100	Metals	Ash/soil	SREL data	Ecological weight-of-evidence support
PAS, PGW & RGW	13 wells	TAL metals, Rads	Groundwater	Definitive	Groundwater Extent, CM
PAB	2	TAL metals, Rads	Surface Water	Definitive	Extent, HHRA, ERA
None	6	Metals	Biota	SREL data	Ecological weight-of-evidence support

Table 1-2. Summary of Groundwater Data

Analyte Name	Total Samples	# Detects	% Detects	Units	Mean DL	Mean Detection	Minimum Detection	Maximum Detection	MCL/ RSL	Max >MCL/ RSL?	# Samples Exceeding MCL/ RSL
Arsenic	52	3	6	µg/L	2.54E+00	1.53E+01	1.30E+00	1.90E+02	1.00E+01	No	0
Barium	52	52	10	µg/L	8.92E+00	3.55E+01	3.84E+00	1.73E+02	2.00E+03	No	0
Beryllium	52	15	29	µg/L	6.92E-01	1.09E+00	1.03E-01	1.06E+01	4.00E+00	Yes	1
Cadmium	32	7	13	µg/L	5.00E-01	1.56E-01	1.30E-01	2.00E-01	5.00E+00	No	0
Chromium	32	3	6	µg/L	1.00E+01	4.20E+00	3.50E+00	5.40E+00	1.00E+02	No	0
Cobalt	52	31	60	µg/L	3.46E+00	9.68E-01	2.70E-01	4.30E+00	1.00E+01	No	0
Copper	52	36	69	µg/L	2.54E+00	1.08E+00	5.02E-01	3.40E+00	1.30E+03	No	0
Gross Alpha	52	25	48	pCi/L	3.96E+00	2.87E+00	6.20E-01	1.82E+01	1.50E+01	Yes	1
Iron	52	37	71	µg/L	6.92E+01	8.03E+02	1.09E+01	5.79E+03	2.60E+04	No	0
Lead	52	36	69	µg/L	3.77E+00	1.05E+00	2.00E-01	6.00E+00	1.50E+01	No	0
Manganese	52	48	92	µg/L	5.08E+00	1.58E+01	3.00E-01	7.16E+01	8.80E+02	No	0
Mercury	10	0	0	µg/L	2.00E-01	ND	ND	ND	ND	NA	NA
Nonvolatile Beta	52	21	40	pCi/L	5.37E+00	2.89E+00	8.40E-01	1.80E+01	NA	NA	NA
Selenium	52	0	0	µg/L	8.85E+00	ND	ND	ND	ND	NA	NA
Silver	32	6	12	µg/L	2.00E+00	4.12E-01	1.30E-01	1.40E+00	1.80E+02	No	0
Tetrachloroethylene (PCE)	10	0	0	µg/L	5.00E-01	ND	ND	ND	5.00E+00	NA	NA
Thallium	48	18	35	µg/L	1.58E+00	1.29E+00	1.57E-01	2.10E+00	5.00E+00	No	0
Trichloroethylene (TCE)	10	0	0	µg/L	5.00E-01	ND	ND	ND	5.00E+00	NA	NA
Tritium	10	7	13	pCi/L	5.41E-01	8.07E-01	1.49E-01	2.01E+00	2.00E+01	No	0
Zinc	52	19	37	µg/L	1.96E+01	9.08E+00	3.23E+00	1.69E+01	1.10E+04	No	0

Table 1-3 Summary of Refined Constituents of Concern

Media	HH RCOCs	Risk Estimate	Total Cumulative Risk
Surface Ash/Soil (0 to 1 Ft)	Resident Arsenic Cesium-137(+D) Potassium-40 Radium-226(+D) Uranium-238(+D)	 5.5E-05 5.5E-05 8.8E-05 1.9E-04 2.9E-06	3.9E-04
	Industrial Worker Arsenic Cesium-137(+D) Potassium-40 Radium-226(+D) Uranium-238(+D)	 1.3E-05 3.3E-05 5.0E-05 1.1E-04 1.4E-06	2.1E-04
	IOU Onsite Worker Arsenic Cesium-137(+D) Potassium-40 Radium-226(+D)	 6.5E-06 1.7E-05 2.4E-05 5.1E-05	9.9E-05
	Adolescent Trespasser Arsenic Cesium-137(+D) Potassium-40 Radium-226(+D)	 3.0E-06 1.3E-05 1.6E-05 3.5E-05	6.7E-05

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section summarizes the technology screening for the WADB and the unit-specific RAOs for soil contamination in relation to the RGOs which have been developed. Remedial alternatives applicable to the WADB are then identified for establishing general response actions.

2.1 Introduction

Technologies for remediating the WADB have been screened. Because there are only a limited number of applicable effective technologies, the screening of general response actions is succinct and is found on Table 2-1.

The technologies considered include the No Action Alternative as a baseline case to compare against the nine criteria of other alternatives as required by the NCP. Land use controls (LUCs) are selected to administratively limit receptor access to contaminated media. Containment (both in situ and ex situ) was selected as an engineered barrier technology and includes a soil cover or capping system and was retained since this is a conventional technology universally used for disposal of solid waste and ash. Finally, excavation (or removal) combined with ex situ containment was selected as a combination of simple, implementable remedial technologies. Containment is also considered a presumptive remedy for metals in soil by the USEPA.

The NCP specifies six criteria for developing this range of remedial technologies:

1. Whenever practical, use treatment to address principal threats posed by the unit;
2. Use engineering controls for waste that poses a relatively low long-term risk or when treatment is impractical;
3. Combine methods (for example, treatment plus engineering controls) to protect human health and the environment;
4. Supplement engineering controls with LUCs to prevent or limit exposure;

5. Whenever practical, use innovative technologies; and
6. Return usable groundwater to beneficial uses or prevent further degradation.

2.2 Remedial Action Objectives

RAOs are site-specific goals defining the extent of cleanup required to achieve protection of human health and the environment. RAOs specify RCOCs, media of concern, protected receptors, potential pathways, and target cleanup goals, and applicable or relevant and appropriate requirements (ARARs). RAOs are based on the nature and extent of contamination, threatened resources, and the potential for human and environmental exposure. They provide a framework for developing remedial alternatives in the FCMS/FS process.

The RAO for the WADB is to: Prevent the IOU on-site worker from exposure to RCOC contaminants in surface ash/soil exceeding 1E-06 risk or SRS background concentrations.

Section 121(d) of CERCLA (CERCLA 1980), as amended by Superfund Amendments and Reauthorization Act (SARA), (SARA 1986), requires that remedial action comply with requirements or standards set forth under Federal and State environmental laws. These are considered ARARs and include action-specific, location-specific, and chemical-specific requirements. SARA requires that the remedial action for a site meet all ARARs unless a waiver is invoked for one of the following reasons:

1. The remedial action is an interim measure where potential final actions will attain the ARAR upon completion.
2. Compliance will result in greater risk to human health and the environment than other options.
3. Compliance is technically impracticable.
4. The remedial action will attain the equivalent of an ARAR.
5. The State has not consistently applied the requirement in similar circumstances.

SARA Section 121(e) exempts any federal, on-site remedial action from administrative requirements for Federal, State, and/or local permits. However, on-site actions still must comply with the substantive, technical aspects of these requirements.

Potential ARARs are classified as either applicable or relevant and appropriate. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance at a CERCLA site. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that do not specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, but nonetheless are well suited to the particular site.

In general, relevant and appropriate requirements involve comparing a number of site-specific factors with those addressed in the statutory or regulatory requirement. Site-specific factors include the characteristics of a remedial action, hazardous substances present at the site, or physical circumstances of the site. In some cases, a requirement can be relevant but not appropriate based on site-specific circumstances and thus may not be selected as an ARAR for the site. Therefore, it is not an ARAR for the site. There is additional flexibility in the determination of relevant and appropriate requirements. It is possible for only part of a requirement to be considered relevant and appropriate in a given case. When the analysis results in a determination that a requirement is both relevant and appropriate, such a requirement must be complied with to the same degree as if it were applicable.

In addition to ARARs, many Federal and State environmental and public health programs include criteria, guidance, and proposed standards that are not legally binding but provide useful approaches or recommendations. These “To-be-considered” (TBC) requirements are non-promulgated advisories or guidance issued by Federal or State government that are not legally binding and do not have the status of potential ARARs. However, TBC requirements can be considered along with ARARs in determining the level of cleanup for protection of human health of the environment.

Three categories of ARARs were defined to clarify how to identify and comply with environmental requirements. They include action-specific, location-specific, and chemical-specific requirements. Action-specific ARARs control or restrict the design, performance, and other aspects of implementation of specific remedial activities. Location-specific ARARs reflect the physiographic and environmental characteristics of the unit or the immediate area, and may restrict or preclude remedial actions depending on the location or characteristics of the unit or the immediate area, and may restrict or preclude remedial action, depending upon the characteristics of the unit. Chemical-specific ARARs are media-specific concentration limits promulgated under Federal or State law. The NCP requires the development of health-based, site-specific levels for chemicals where such promulgated limits for the particular contaminant and/or media do not exist and where there is concern with their potential health or environmental effects.

Table 2-2 summarizes potential ARARs for the WADB.

2.2.1 Development of Remediation Goals

Risk-based RGOs for the RCOCs identified for the WADB are summarized on Table 2-3. The most restrictive RGO is defined as the lowest of the human health, ecological, CM, PTSM, and ARAR RGOs for each RCOC. For the WADB, only HH RCOCs have been identified. Refer to Appendix B.

In contrast to the most restrictive RGOs, the most likely RGOs consider two additional factors: 1) anticipated land use, and 2) comparisons to background levels. The current land use for the RAO is industrial with the United States Department of Energy (USDOE) maintaining control of the land in perpetuity. In the long term, if the property is ever transferred to non-federal ownership, the United States Government will take those actions necessary pursuant to Section 120(h) of CERCLA. According to the SRS

Future Use Project Report (USDOE 1996) residential uses of SRS land should not be permitted.

A range of RGOs is developed for each medium in which RCOCs are identified to provide a basis for selecting the final remedial levels. RGO calculations for Dunbarton Bay are provided in Appendix E.

The selection of the RCOCs and final RGOs is subject to approval by the USDOE, SCDHEC, and USEPA Core Team. In addition, the Citizens Advisory Board (CAB) and the SRS Natural Resource Trustees may serve the USDOE, SCDHEC, and USEPA Core Team in an advisory role.

The development of RGOs for Dunbarton Bay is described below.

2.2.1.1 Human Health Risk-based Remedial Goal Options

The HHRA is presented in Appendix B of this document. HH RCOCs were identified in ash/soil media for all four of the receptor scenarios that were evaluated in the HHRA, and RGOs are provided for each as appropriate. No HH RCOCs were identified for the surface water media. Human health risk-based RGOs are developed in accordance with the protocol for Human Health Remedial Goal Options (WSRC 2006a). Risk-based RGOs are calculated for the future resident, future industrial worker, onsite worker and adolescent trespasser scenarios at various target risk levels (1E-06, 1E-05, and 1E-04). The HH RGOs for ash/soil media at WADB are provided in Appendix E, Table E-1.

2.2.1.2 Principal Threat Source Material Remedial Goal Options

The PTSM evaluation is also presented in Appendix B of this document. No PTSM RCOCs were identified for the ash/soil media at WADB; therefore, PTSM RGOs are not developed.

2.2.1.3 Ecological Risk-Based Remedial Goal Options

The ERA is presented in Appendix C of this document. No ecological RCOCs were identified for the ash/soil or surface water media at WADB; therefore, ecological RGOs are not developed.

2.2.1.4 Contaminant Migration/Groundwater Remedial Goal Options

The CM analysis is presented in Appendix D of this document. No contaminant migration RCOCs were identified for the ash/soil medium at WADB; therefore, contaminant migration RGOs are not developed.

In addition, an evaluation of the groundwater medium is also presented in Appendix D of this document. No groundwater RCOCs were identified for WADB; therefore, groundwater RGOs are not developed.

2.2.2 Most Restrictive and Most Likely Remedial Goal Options

Risk-based RGOs for the RCOCs identified for WADB are summarized in Table 2-3. Since RCOCs are identified for human receptors only, the most restrictive RGO is identified as the lowest of the HHRA RGOs. There are no PTSM, ERA, CM or GW RGOs identified for WADB.

In contrast to the most restrictive RGOs, the most likely RGOs also consider a comparison to background levels. Because of the inherently conservative nature of the risk assessment and RGO calculations, it is possible for the risk-based RGO to be less than what occurs naturally in unimpacted background soil. In this case, the RGO defaults to the background concentration to be technically practical to achieve. The background concentration is set as the 95th percentile for unimpacted SRS-wide soil (Refer to Appendix B-2 in WSRC 2006b), except for Cs-137 which is from Appendix B-1 (0- to 0.3-m [0- to 1-ft interval]) of the same reference.

The most restrictive RGOs and most likely RGOs presented in this chapter are a good starting point for developing remedial alternatives. Final remedial goals will be agreed upon by USDOE, SCDHEC, and USEPA concurrent with selection of a remedial action. Final remedial goals will be documented in the Record of Decision (ROD).

2.3 General Response Actions

This section identifies and screens four general response actions for the WADB, identifies potential remedial technologies for each general response action, and screens remedial technologies with respect to effectiveness, implementability, and cost for the WADB.

Characterization of the WADB has been completed and an assessment of the nature and extent of contamination is presented in this submittal of the FCMS/FS.

The initial list of general response actions and technologies applicable to the wetland is based upon the likely response actions determined at the previous WADB scoping meeting as well as past experience with similar remedial action projects and evaluation of USEPA documentation for remedial technologies including:

- Superfund Innovative Technology Evaluation Program (SITE) Technology Profiles, 10^{th} Edition (USEPA 1999)
- USEPA Database Remediation and Characterization Innovative Technologies (REACHIT) (USEPA 2003)
- Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (USEPA 1988)

2.4 Identification and Screening of Technologies

The purpose of this section is to describe the applicability of the specific technology types, including process options, identified for the WADB. Identified technologies are screened using the NCP (also known as the National Contingency Plan) criteria for effectiveness, implementability, and cost. Technologies that pass this screening are retained and carried forward to develop remedial action alternatives.

General response actions are operable unit-specific actions that achieve remedial action objectives and satisfy the requirements of the NCP (40 Code of Federal Regulations [CFR] Part 300 USEPA 1994). Four general response actions have been identified for the WADB:

2.5 General Response Actions

1. No Action
2. Land Use Controls
3. Containment, both in situ and ex situ
4. Excavation Combined with Ex Situ Containment

These response actions may be implemented singularly and/or in combination with other remedial alternatives.

2.5.1 No Action

The No Action response is not a technology but is required by the NCP as a baseline for comparison with other remedial actions. In this scenario, the ash remains in place with no efforts made to control access, limit exposure or to monitor, remove, treat, contain, excavate, or otherwise mitigate the potential spread of contaminants in the WADB. There is no reduction in risk, toxicity, mobility or treatment of contaminants.

2.5.2 Land Use Controls

LUCs include access controls and administrative measures that minimize the potential for human exposure to contaminants. Although institutional controls (such as deed restrictions on land or water use) are usually not effective in achieving RAOs, they can, in many instances be protective of human health. Generally, LUCs are relatively simple and inexpensive to implement and are retained for use, if necessary, in conjunction with other remedial alternative(s) ultimately selected at the area or as a stand-alone alternative. LUCs that already exist at SRS and that can be implemented at the WADB include: physical access controls (e.g., fencing) and administrative controls.

Access Controls involve temporary or permanent physical restrictions to prevent or reduce human exposure to contaminants. Controls also can be used to prevent vandalism of on-site remedial equipment or disturbance of containment systems. Regular monitoring and maintenance of access controls are required for this technology to effectively deter site entry. Access controls may include, but are not limited to signs, fencing, barricades, covers, or exclusion devices.

Access controls that are effective in minimizing the potential for human exposure from direct contact with contaminated media are relatively easy to implement and low in cost when compared to other technologies. However, access controls would not be effective in preventing off-site contaminant migration or exposure to ecological receptors. Access controls are retained to deter intruders and will be part of all alternatives in which contaminated media are left on the unit at risk levels that prohibit unrestricted use.

Administrative controls can be used to prevent or reduce future human exposure to contaminants remaining on the site. For example, excavation permit restrictions can be used to permanently prohibit excavation or subsurface construction. Administrative controls also can be temporary measures used while other remedial actions are taking place.

In the long-term, if the property is ever transferred to nonfederal ownership, the United States Government would, in compliance with Section 120(h) of CERCLA, create a deed for the new property owner. The deed would include notification disclosing the former waste management and disposal activities as well as remedial actions taken onsite and any continuing groundwater monitoring commitments. Unit-specific land use controls for the wetland area will be included in the final ROD.

Administrative controls are low cost, provide a degree of protection of human health by breaking exposure pathways, and are relatively simple to implement.

2.5.3 Containment

Containment technologies involve the construction of engineered barriers to isolate contaminated media. Containment may be 1) in situ (at the location of the waste unit) or 2) ex situ (away from the location of the waste unit). Properly constructed and maintained engineered barriers are effective and reliable at minimizing or eliminating human and ecological exposure to contaminants and minimize leaching, direct radiation exposure, mobility, and bio-uptake of contaminated media. The use of engineered containments such as capping and soil cover systems are very effective and have reasonable permanence, but must be maintained (monitored and repaired as a part of LUCs) as long as the contaminated media remains in place. Containments can be constructed of natural material and/or synthetic material (i.e., geotextile membranes); however, containments are most effective when they are constructed of natural material. Effective slopes need to be planned into the design to prevent erosion, but still enhance runoff of precipitation away from the cover to prevent infiltration through the upper containment layers. Other key design features of properly designed containment also require a well-established vegetation layer to promote evapotranspiration, surficial drainage system, and a drainage layer to divert infiltration water to the external drainage system.

2.5.4 Excavation Combined with Ex Situ Containment

Excavation (or removal) can be accomplished by scraping, cutting, digging, scooping, and vacuuming, with heavy earth moving equipment and using conventional construction methods. Excavation is both effective and permanent since wastes are removed from the waste unit for disposal and are then isolated in an approved containment facility. In situ containment may be a stand-alone remedial action; ex situ containment would require a combination of remedial actions to collect, consolidate, and transport waste from the WADB subunit to the ex situ containment facility. Because the contaminated media is both removed and then isolated by an engineered barrier it is effective and reliable at eliminating human and ecological exposure to contaminants and prevents leaching, direct radiation exposure, reduces mobility, and bio-uptake of contaminated media. In the case of the WADB, the ash would be consolidated and excavated with heavy earth moving equipment and transported to an approved containment facility. The containment facility could be constructed near the waste unit or be an existing on-SRS facility (such as H-Area Ash Basin) or an off-SRS facility (such as Three Rivers Landfill).

2.6 Screening of Technologies and Selection of Representative Technologies

Various technologies and approaches exist for implementing the four general response actions for the WADB. The NCP requires these potential technologies be screened against effectiveness, implementability and cost. All the technology types suitable for this project are conventional and reliable. Table 2-1 summarizes the general response actions, remedial technologies, relative costs, and synopsis of the screening.

Effectiveness: An effective technology must achieve the specified RAOs, be compatible with the contaminant characteristics and waste unit conditions, and be protective of human health and the environment in both short-term and long-term scenarios. Technologies that do not meet RAOs are significantly less effective than comparable approaches or that have not been demonstrated successfully at similarly contaminated waste units are eliminated from further consideration.

Implementability: Technologies are evaluated based on the technical feasibility, availability of resources and equipment, and the administrative or institutional feasibility of implementation. Implementable technologies are those that can be readily installed in a cost-effective and timely fashion and that will not elicit substantial public concern from the surrounding community. Mobilization and permitting requirements must be workable and must have been previously demonstrated at similar projects. Consideration is also given to regulatory constraints such as waste handling, disposal, and treatment requirements that would affect the implementation of a technology.

Cost: A qualitative cost evaluation is provided so that comparisons can be made between general response actions. Qualitative evaluations take into consideration capital costs and operation and maintenance (O&M) costs. For screening purposes, the cost of technologies are typically described as high, medium, or low relative to others in the same general category.

2.6.1 No Action (Retained as Required)

This response action would not require the deployment of any technology to reduce the toxicity, mobility, or volume of the ash or otherwise mitigate the potential spread of contaminants from the ash in the wetlands. The No Action response action could be readily implemented and would have no cost. There would be no reduction in risk and the RAO would not be attained. There is also no 5-year remedy review under CERCLA. Therefore, it is not effective; it is implementable and is the least costly response action.

2.6.2 Land Use Controls (Retained)

This response action leaves hazardous substances in place that present a potential risk to the IOU on-site worker receptor. LUCs would be required to be in place as long as the ash remains in the WADB. Both administrative and engineering controls would prevent exposure of potential human receptors to contaminants by limiting access to the land or resource use. LUCs are relatively simple and inexpensive to implement and may be retained as an independent alternative or in conjunction with another remedial alternative(s). LUCs may also be used to supplement engineering controls to ensure their continued effectiveness. Engineering barriers such as warning or no trespassing signs, fencing, and barricades can prevent human access to contaminated media.

LUCs are relatively low in cost, provide a high degree of protection of human health, and are relatively simple to implement. LUCs would not be protective in preventing exposure of ecological receptors. However, LUCs would prevent further damage to the wetland area caused by earth moving activities from more aggressive removal technologies. LUCs are retained for further consideration in the detailed analysis.

2.6.3 In Situ Containment (Rejected), Ex Situ Containment (Retained)

Containment technologies involve the construction of engineered caps and soil cover systems to isolate contaminated media. Technologies include capping, horizontal barriers, synthetic membrane covers/liners, and low permeability soil cover systems. Properly constructed and maintained containments are effective and reliable at preventing direct exposure to contaminants and at minimizing leaching, erosion, mobility, and bio-uptake.

The effectiveness of containment technologies depends upon the materials used, the design and effectiveness of the drainage layer, design and effectiveness of the capping layer, establishment of a vegetative layer, and effective slope of the cover layer to encourage runoff and reduce infiltration. Natural clay materials are less susceptible to perforation, but synthetic materials can tear or be easily perforated during installation thus compromising the integrity of the cover. Cover integrity must be maintained for as long as contaminants will persist or until degradation or decay of the contaminants renders them harmless.

In situ containment systems constructed in the WADB may not be considered best engineering practice since the area is subject to flooding, poor drainage, and erosion. Also wetland soils are hydric and contain large quantities of soil moisture and organic matter which does not provide a stable construction foundation. The possibility for the breach of the containment is high since hydric soils have high shrink-swell capacity and would subject the containment system to differential settlement and ultimate failure. Additionally, the construction of a containment system would not comply with location-specific ARARs and could cause significant damage to the ecosystem of the Dunbarton Bay. For these reasons in situ containment is rejected.

Ex situ containment can be located to areas without hydric soils and where flooding will not occur. Maintenance activities include inspections, vegetation control, cover maintenance, and monitoring for settlement and erosion. For these reasons ex situ containment (outside of the WADB) is retained.

Relative cost for containment is considered relatively high. Containment is considered a standard construction practice that is not expected to present impediments on stable soils, but will pose significant engineering challenges and unacceptable construction costs to provide foundation stability on hydric soils. Therefore, in situ containment is rejected and ex situ containment is retained.

2.6.4 Excavation Combined with Ex Situ Containment (Retained)

Excavation combined with ex situ containment (excavation and disposal) of contaminated soil media in an appropriate containment facility is one of the most aggressive approaches to remediation. Contaminated ash media could be excavated and hauled a short distance where it would be contained at an approved on-site ash disposal facility located on the SRS proper, such as H-Area Ash Basin. Similarly the ash could be excavated and trucked to an approved off-SRS ash disposal facility such as the Three Rivers Landfill. Removing contaminated ash media from the WADB would lower risk levels for the IOU on-site worker scenario by permanently removing and disposing the ash in an approved waste disposal facility.

The earthwork required for excavating the ash media is a standard construction practice and is readily accomplished. The cost of this action could be substantial based upon the volume of contaminated media and the distance the ash must be hauled to an approved off-SRS waste disposal facility. The cost may be more reasonable to excavate and haul the ash to an existing waste management facility in H-Area. Due to its effectiveness, this approach is retained for further consideration.

Table 2-1. Summary of the Screening of Technologies

Likely Response Action	General Response Action	Remedial Technology	Description and Evaluation Based on Effectiveness, Implementability, and Cost	Wetland at Dunbarton Bay Subunit	Status
No Action	No Action	None	No action is required by National Hazardous Substances Pollution Contingency Plan (NCP) to serve as a baseline against other technologies and alternatives. Not effective in meeting RAOs; readily implementable. Low cost.	Evaluated	Required
Institutional Controls/ Engineering Controls	Land Use Controls	ECs (i.e., Access Controls)	Installation of barriers and signs for access control. Effective in restricting land use. Readily implemented. Low cost.	Evaluated	Retained
		ICs (i.e., Administrative Controls)	Administrative controls provided by SRS Site Use/Site Clearance procedures; work controls; mandatory worker use of health and safety plans; SRS access controls including security procedures; 24-hour surveillance; controlled entry systems; and warning signs at SRS boundary. Low cost.	Evaluated	Retained
Containment a) In situ b) Ex situ Cover system or capping	Cover system or capping	Low permeability soil cover system or capping	In situ containment is not readily implementable without considerable destruction of the ecosystem from construction. Construction impediments due to location and drainage. High cost. Ex situ containment reduces both infiltration, mobility and provides isolation barrier to prevent receptor exposure. Ex situ containment is considered feasible based on removal of ash from wetlands. High cost.	Evaluated	a) In situ Rejected b) Ex situ Retained
Excavation combined with ex situ containment	Excavation with ex situ containment can be: 1) On-SRS approved disposal facility 2) Approved off-SRS facility	Excavate and haul to an ex situ containment facility	Ash is excavated and removed from a portion of the wetland and disposed of at an approved containment facility. Disposal facility will meet requirements of SC R.61-107. Effective for achieving RAO and protecting on-site worker. Protective of the sensitive ecosystem of the Carolina Bay. High cost.	Evaluated	Retained

Table 2-2. Potential ARARs and TBC Criteria for the WADB FCMS/FS ARARs

LOCATION-SPECIFIC ARARs/TBC			
Location Characteristics	**Requirements**	**Prerequisite**	**Citation**
Floodplains and Wetlands			
Presence of wetlands as defined in 10 *CFR* 1022.4	Avoid, to the extent possible, the long- and short-term adverse effects associated with destruction, occupancy, and modification of wetlands and floodplains.	DOE actions that involve potential impacts to, or take place within, wetlands – **applicable.**	10 *CFR* 1022.3(a)
	Take action, to extent practicable, to minimize destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands.		10 *CFR* 1022.3(a)(7) and (8)
	Undertake a careful evaluation of the potential effects of any new construction in wetlands. Identify, evaluate, and as appropriate, implement alternative actions that may avoid or mitigate adverse impacts on wetlands.		10 *CFR* 1022.3(b) and (d)
	If no practicable alternative to locating or conducting the action in the wetland is available, then before taking action, design or modify the action in order to minimize potential harm to or within the wetland, consistent with the policies set forth in E.O. 11990.		10 *CFR* 1022.14(a)

Table 2-2. Potential ARARs and TBC Criteria for the WADB FCMS/FS ARARs *(Continued)*

LOCATION-SPECIFIC ARARs/TBC			
Location Characteristics	**Requirements**	**Prerequisite**	**Citation**
Floodplains and Wetlands (Cont'd/End)			
Location encompassing *aquatic ecosystem* as defined in 40 CFR 230.3(c)	No discharge of dredged or fill material into an aquatic ecosystem is permitted if there is a practicable alternative that would have less adverse impact. No discharge of dredged or fill material shall be permitted unless appropriate and practicable steps in accordance with 40 CFR 230.70 *et seq.* have been taken that will minimize potential adverse impacts of the discharge on the aquatic ecosystem.	Action that involves the discharge of dredged or fill material into waters of the United States, including jurisdictional wetlands – **applicable.**	40 CFR 230.10(a) 40 CFR 230.10(d)
	Must comply with the substantive requirements of the NWP 38, General Conditions, as appropriate, any regional or case-specific conditions recommended by the Corps District Engineer, after consultation. Note: Despite that consultation may be considered an administrative requirement, it should be performed to ensure activities are in compliance with substantive provisions of the permit.	On-site CERCLA action conducted by Federal agency that involves discharge of dredged or fill material into *waters of the United States*, including jurisdictional wetlands – **relevant and appropriate**.	Nationwide Permit (38) – Cleanup of Hazardous and Toxic Waste 33 *CFR* 323.3(b)
Presence of wetlands	Requires Federal agencies to evaluate action to minimize the destruction, loss or degradation of wetlands and to preserve and enhance beneficial values of wetlands.	Actions that involve potential impacts to, or take place within, wetlands – **TBC**	Executive Order 11990 – *Protection of Wetlands* - Section 1.(a)
Endangered, Threatened or Rare Species			
Presence of migratory birds and their habitats	No person may take, possess, import, export, transport, sell, purchaser, barter or offer for sale, purchase or barter, any migratory bird, or the parts, nests, or eggs of such bird except as may be permitted under the terms of a valid permit.	If action is likely to impact migratory birds – **applicable**.	16 *USC* 703-704 – Migratory Bird Treaty Act

Table 2-2. Potential ARARs and TBC Criteria for the WADB FCMS/FS ARARs *(Continued)*

LOCATION-SPECIFIC ARARs/TBC			
Location Characteristics	**Requirements**	**Prerequisite**	**Citation**
Historical, Archeological or Cultural Resources			
Presence of archeological or cultural artifacts	No person may excavate, remove, damage, or otherwise alter or deface, or attempt to excavate, remove, damage, or otherwise alter or deface any archaeological resource located on public lands unless such activity is pursuant to a permit issued under § 7.8 or exempted by § 7.5(b) of this part. *Note: Prior to removal activities existing Site Use process requires approval by the Savannah River Archaeological Research Program. The SRARP is a division of the South Carolina Institute of Archaeology and Anthropology (SCIAA) at the University of South Carolina. The SRARP manages the archaeological and other historic resources for the U.S. Department of Energy.*	Excavation and/or removal of archaeological resources from public lands – **applicable**.	43 *CFR* Part 7 – implementing the Archaeological Resources Protection Act of 1979.

ACTION-SPECIFIC ARARs/TBC			
Action	**Requirements**	**Prerequisite**	**Citation**
All Land-Disturbing Activities (i.e., excavation, clearing, grading, etc.)			
Managing storm water runoff from land-disturbing activities	Must comply with the substantive requirements for stormwater management and sediment control of *NPDES General Permit No. SCR100000* .	Large and small construction activities (as defined in R. 61-9) of more than 1 acre of land – **applicable.**	SCDHEC R. 61-9.122.41 ~~SCDHEC R. 61-9.122.26(c)~~ NPDES General Permit No. SCR100000
	The stormwater management and sediment control plan shall contain at a minimum the information provided in the following subsections:	Activities involving more than two (2) acres and less than five (5) acres of actual land disturbance which are not part of a larger common plan of development or sale – **applicable.**	SCDHEC R. 72-307 I. – *South Carolina Storm Water Management and Sediment Reduction Regulations*

Table 2-2. Potential ARARs and TBC Criteria for the WADB FCMS/FS ARARs *(Continued)*

ACTION-SPECIFIC ARARs/TBC			
Action	**Requirements**	**Prerequisite**	**Citation**
All Land-Disturbing Activities (i.e., excavation, clearing, grading, etc.) *(Cont'd/End)*			
	A plan for temporary and permanent vegetative and structural erosion and sediment control measures which specify the erosion and sediment control measures to be used during all phases of the land disturbing activity and a description of their proposed operation;		SCDHEC R. 72-307 I.(3)(d)
	Provisions for stormwater runoff control during the land disturbing activity and during the life of the facility meeting the following requirements of subsections (e)1 and 2.		SCDHEC R. 72-307 I.(3)(e)
Managing fugitive dust emissions from land disturbing activities	Emissions of fugitive particulate matter shall be controlled in such a manner and to the degree that it does not create an undesirable level of air pollution.	Activities that will generate fugitive particulate matter (Statewide) – applicable	SCDHEC R. 61-62.6 Section III(a)- *Control of Fugitive Particulate Matter Statewide*
Waste Characterization and Storage (e.g., excavated coal ash, contaminated soils/sediments, debris)			
Characterization of solid waste	Must determine if the solid waste is excluded from regulation under 40 *CFR* 261.4.	Generation of solid waste as defined in 40 *CFR* 261.2 – **applicable.**	40 *CFR* 262.11(a) SCDHEC R. 61-79 262.11*(a)*
	Must determine if waste is listed as hazardous waste in subpart D of 40 *CFR* Part 261.	Generation of solid waste which is not excluded under 40 *CFR* 261.4(a) – **applicable.**	40 *CFR* 262.11(b) SCDHEC R. 61-79 262.11*(b)*

Table 2-2. Potential ARARs and TBC Criteria for the WADB FCMS/FS ARARs *(Continued)*

ACTION-SPECIFIC ARARs/TBC			
Action	**Requirements**	**Prerequisite**	**Citation**
Waste Characterization and Storage (e.g., excavated coal ash, contaminated soils/sediments, debris) *(Cont'd)*			
	Must determine whether the waste is identified in subpart C of 40 *CFR* Part 261 by either: 1) Testing the waste according to the methods set forth in subpart C of 40 CFR part 261, or according to an equivalent method approved by the Administrator under 40 CFR 260.21; or 2) Applying knowledge of the hazard characteristic of the waste in light of materials or processes used.	Generation of solid waste that is not excluded under 40 *CFR* 261.4 – **applicable**.	40 *CFR* 262.11(c) SCDHEC R. 61-79 262.11*(c)*
	Must refer to Parts 261, 262, 264, 265, 266, 268, and 273 of Chapter 40 for possible exclusions or restrictions pertaining to management of the specific waste.	Generation of solid waste which is determined to be hazardous waste – **applicable.**	40 CFR 262.11(d) SCDHEC R. 61-79 262.11*(d)*
Determinations for management of *hazardous* waste[1]	Must determine each EPA Hazardous Waste Number (waste code) applicable to the waste in order to determine the applicable treatment standards under 40 CFR 268 *et seq.* *<u>Note</u>:* This determination may be made concurrently with the hazardous waste determination required in Sec. 262.11 of this chapter.	Generation of hazardous waste for storage, treatment or disposal – **applicable.**	40 CFR 268.9(a) SCDHEC R. 61-79 268.9*(a)*
	Must determine the underlying hazardous constituents [as defined in 40 CFR 268.2(i)] in the characteristic waste.	Generation of RCRA characteristic hazardous waste (and is not D001 non-wastewaters treated by CMBST, RORGS, or POLYM of Section 268.42 Table 1) for storage, treatment or disposal – **applicable.**	40 CFR 268.9(a) SCDHEC R. 61-79 268.9*(a)*
	Must determine if the hazardous waste meets the treatment standards in 40 CFR 268.40, 268.45, or 268.49 by testing in accordance with prescribed methods or use of generator knowledge of waste. *Note:* This determination can be made concurrently with the hazardous waste determination required in 40 CFR 262.11.	Generation of hazardous waste for storage, treatment or disposal – **applicable.**	40 CFR 268.7(a) SCDHEC R. 61-79 268.7*(a)* (1)

Table 2-2. Potential ARARs and TBC Criteria for the WADB FCMS/FS ARARs *(Continued)*

ACTION-SPECIFIC ARARs/TBC			
Action	**Requirements**	**Prerequisite**	**Citation**
Waste Characterization and Storage (e.g., excavated coal ash, contaminated soils/sediments, debris) *(Cont'd)*			
Disposal of Solid Waste Off Site (e.g., excavated ash, contaminated soils/sediment, debris)			
Disposal of *solid waste* off-SRS	Disposal of solid waste at facilities and/or sites permitted or registered by the Department for processing or disposal of that waste stream. Waste must meet State classification system for the permitted facilities.	Generation of solid waste intended for off-SRS disposal – **Applicable.**	SCDHEC R. 61-107.15)
Disposal of Hazardous Waste Off Site (e.g., excavated ash, contaminated soils/sediment, debris)			
Disposal of RCRA-*hazardous waste* in off-site, land-based unit[1]	May be land disposed if it meets the requirements in the table "Treatment Standards for Hazardous Waste" at 40 CFR 268.40 before land disposal.	Land disposal, as defined in 40 CFR 268.2, of restricted RCRA waste – **applicable.**	40 CFR 268.40(a) SCDHEC R. 61-79 268.40*(a)*
Disposal of Hazardous Waste Off Site (e.g., excavated coal ash, contaminated soils/sediments, debris) *(Cont'd/End)*			
	All underlying hazardous constituents [as defined in 40 CFR 268.2(i)] must meet the Universal Treatment Standards, found in 40 CFR 268.48 Table UTS prior to land disposal.	Land disposal of restricted RCRA characteristic wastes (D001-D043) that are not managed in a wastewater treatment system that is regulated under the CWA, that is CWA equivalent, or that is injected into a Class I nonhazardous injection well – **applicable**	40 CFR 268.40(e) SCDHEC R. 61-79 268.40*(e)*
	Must be treated according to the alternative treatment standards of 40 CFR 268.49(c) <u>or</u> Must be treated according to the UTSs [specified in 40 CFR 268.48 Table UTS] applicable to the listed and/or characteristic waste contaminating the soil prior to land disposal.	Land disposal, as defined in 40 CFR 268.2, of restricted hazardous soils –**applicable**	40 CFR 268.49(b) SCDHEC R. 61-79 268.49*(b)*

Table 2-2. Potential ARARs and TBC Criteria for the WADB FCMS/FS ARARs *(Continued)*

ACTION-SPECIFIC ARARs/TBC			
Action	**Requirements**	**Prerequisite**	**Citation**
Waste Characterization and Storage (e.g., excavated coal ash, contaminated soils/sediments, debris) *(Cont'd)*			
Disposal of Hazardous Waste Off Site (e.g., excavated coal ash, contaminated soils/sediments, debris) *(Cont'd/End)*			
	To determine whether a hazardous waste identified in this section exceeds the applicable treatment standards of 40 CFR 268.40, the initial generator must test a sample of the waste extract or the entire waste, depending on whether the treatment standards are expressed as concentration in the waste extract or waste, or the generator may use knowledge of the waste. If the waste contains constituents (including UHCs in the characteristic wastes) in excess of the applicable UTS levels in 40 CFR 268.48, the waste is prohibited from land disposal, and all requirements of part 268 are applicable, except as otherwise specified.	Land disposal of RCRA toxicity characteristic wastes (D004-D011) that are newly identified – **applicable**	40 CFR 268.34(f) SCDHEC R. 61-79 268.34*(f)*
Disposal of RCRA-*hazardous waste debris* in off-site, land-based unit[1]	Must be treated prior to land disposal as provided in 40 CFR 268.45(a)(1)-(5) unless EPA determines under 40 CFR 261.3(f)(2) that the debris no longer contaminated with hazardous waste <u>or</u> the debris is treated to the waste-specific treatment standard provided in 40 CFR 268.40 for the waste contaminating the debris.	Land disposal, as defined in 40 CFR 268.2, of restricted RCRA-hazardous debris – **applicable**	40 CFR 268.45(a) SCDHEC R. 61-79 268.45*(a)*

Table 2-2. Potential ARARs and TBC Criteria for the WADB FCMS/FS ARARs *(Continued)*

ACTION-SPECIFIC ARARs/TBC			
Action	**Requirements**	**Prerequisite**	**Citation**
Transportation of Wastes			
Transportation of hazardous materials	Shall be subject to and must comply with all applicable provisions of the HMTA and DOT HMR at 49 CFR 171-180.	Any person who, under contract with a department or agency of the federal government, transports "in commerce," or causes to be transported or shipped, a hazardous material – **applicable**	49 CFR 171.1(c)
Transportation of samples (i.e. solid waste, soils and wastewaters)	Are not subject to any requirements of 40 CFR Parts 261 through 268 or 270 when: • the sample is being transported to a laboratory for the purpose of testing; or • the sample is being transported back to the sample collector after testing. • the sample is being stored by sample collector before transport to a lab for testing.	Samples of solid waste <u>or</u> a sample of water, soil for purpose of conducting testing to determine its characteristics or composition – **applicable**	40 CFR 261.4(d)(1)(i)-(iii) SCDHEC R. 61-79 261.4*(d)* (1)
	In order to qualify for the exemption in 40 CFR 261.4 (d)(1)(i) and (ii), a sample collector shipping samples to a laboratory must: • Comply with U.S. DOT, U.S. Postal Service, or any other applicable shipping requirements. • Assure that the information provided in (1) thru (5) of this section accompanies the sample. Package the sample so that it does not leak, spill, or vaporize from its packaging.		40 CFR 261.4(d)(2)(i) 40 CFR 261.4(d)(2)(i)(A)and (B) SCDHEC R. 61-79 261.4*(d)* (2)(i)(A) and (B)
Transportation of hazardous waste *on-site*[1]	The generator manifesting requirements of 40 CFR 262.20262.32(b) do not apply. Generator or transporter must comply with the requirements set forth in 40 CFR 263.30 and 263.31 in the event of a discharge of hazardous waste on a private or public right-of-way.	Transportation of hazardous wastes on a public or private right-of-way within or along the border of contiguous property under the control of the same person, even if such contiguous property is divided by a public or private right-of-way – applicable	40 CFR 262.20(f) SCDHEC R. 61-79 262.20(f)

Table 2-2. Potential ARARs and TBC Criteria for the WADB FCMS/FS ARARs *(Continued)*

ACTION-SPECIFIC ARARs/TBC			
Action	**Requirements**	**Prerequisite**	**Citation**
Transportation of Wastes *(Cont'd/End)*			
Transportation of hazardous waste *off-site*	Must comply with the generator requirements of 40 CFR 262.2̃023 for manifesting, Sect. 262.30 for packaging, Sect. 262.31 for labeling, Sect. 262.32 for marking, Sect. 262.33 for placarding, Sect. 262.40, 262.41(a) for record keeping requirements, and Sect. 262.12 to obtain EPA ID number.	Generator who initiates the off-site shipment of RCRA-hazardous waste – **applicable**	40 CFR 262.10(h) SCDHEC R. 61-79 262.10*(h)*
CHEMICAL-SPECIFIC ARARs (*None Identified*)			

[1] The requirements from 40 CFR Part 262, 264, and 268 contained in this table regarding characterization, storage, and disposal of hazardous waste will be triggered if any generated wastes, including ash, soil or debris are characterized as RCRA hazardous wastes.

ARAR = applicable or relevant and appropriate requirement
CFR = Code of Federal Regulations
CWA = Clean Water Act
DEACT = deactivation
DOT = U.S. Department of Transportation
EPA = U.S. Environmental Protection Agency
HMR = Hazardous Materials Regulations
HMTA = Hazardous Materials Transportation Act
LDR = Land Disposal Restrictions
RCRA = Resource Conservation and Recovery Act of 1976
SCDHEC = South Carolina Department of Health and Environmental Control
TCLP = Toxicity Characteristic Leaching Procedure
UHC = underlying hazardous constituents
UTS = Universal Treatment Standard
WWTU = Waste Water Treatment Unit

Table 2-3. RGOs for Wetland at Dunbarton Bay Subunit

MEDIA	RCOC[1]	UNITS	ARAR[2]	HHRA Future Resident[3]	HHRA Industrial Worker[4]	HHRA Onsite Worker[5]	HHRA Adolescent Trespasser[6]	PTSM[7]	ERA[8]	CM[9]	Most Restrictive RGO[10]	SRS Background 95th % tile[11]	Most Likely RGO[12]
Ash / Soil	Arsenic	mg/kg	---	0.39	1.6	3.3	7.1	---	---	---	0.39	*8.2*	8.2
	Cesium-137(+D)	pCi/g	---	0.0623	0.103	0.204	0.272	---	---	---	0.0623	*0.34*	0.34
	Potassium-40	pCi/g	---	0.150	0.265	0.552	0.819	---	---	---	0.150	*3.3*	3.3
	Radium-226(+D)	pCi/g	---	0.0127	0.0223	0.0464	0.0688	---	---	---	0.0127	*1.2*	1.2
	Uranium-238(+D)	pCi/g	---	0.725	1.49	NA[13]	NA[13]	---	---	---	0.725	*1.2*	1.2
Surface Water	None	---	---	---	---	---	---	---	---	---	---	---	---
Groundwater	None	---	---	---	---	---	---	---	---	---	---	---	---

1 - RCOC = refined constituent of concern

2 - ARAR = applicable or relevant and appropriate requirement.

3 - HHRA Resident = human health risk assessment. RGOs calculated for the future resident at a target risk of 1E-06. RGO calculations are presented in Appendix E.

4 - HHRA Industrial Worker = human health risk assessment. RGOs calculated for the future industrial worker at a target risk of 1E-06. RGO calculations are presented in Appendix E.

5 - HHRA Onsite Worker = human health risk assessment. RGOs calculated for the onsite worker at a target risk of 1E-06. RGO calculations are presented in Appendix E.

6 - HHRA Adolescent Trespasser = human health risk assessment. RGOs calculated for the adolescent trespasser at a target risk of 1E-06. RGO calculations are presented in Appendix E.

7 - PTSM = principal threat source material evaluation. No RCOCs identified (Appendix B).

8 - ERA = ecological risk assessment. No RCOCs identified (Appendix C).

9 - CM = contaminant migration analysis. No RCOCs identified (Appendix D).

10 - Most Restrictive RGO = the lesser of the ARAR, HHRA, PTSM, ERA and CM RGOs.

11 - SRS 95th %tile = ninety-fifth percentile from the *SRS Background Soils Statistical Summary Report,* Appendix B-2 (all depths), dated October 2006. Exception is Cs-137, which is from Appendix B-1 (0-1 ft).

12 - Most Likely RGO = the most restrictive risk-based RGO if it is greater than background concentrations. If the most restrictive risk-based RGO is less than the background concentration, then the RGO defaults to the background value. Sources of the RGOs in this column are highlighted in italics in the table.

13 - NA = not applicable. U-238(+D) not identified as a HH RCOC for the onsite worker or adolescent trespasser receptor scenarios.

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3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

Potential alternatives have been developed to address the ash plume at the WADB. In accordance with the NCP, it is desirable, to offer a range of diverse alternatives to compare during the detailed analysis. The range of alternatives includes options that 1) reduce the contaminant volume and need for long-term management, or 2) limit future exposure to contaminated media. Some alternatives have been developed that involve little or no treatment, yet provide protection to human health and the environment by preventing or controlling exposure to, or migration of, the contaminants through LUCs. As required by the NCP, the No Action alternative is provided as a baseline for comparison.

The RAO for the WADB is:

- Prevent IOU on-site worker from exposure to contaminants in surface/ash soil at concentrations exceeding 1E-06 risk or SRS background concentrations.

After screening, the retained general response actions and treatment technologies were combined to develop the remedial alternatives. Each of the remedial alternatives, with the exception of the No Action alternative, can attain the RAO either individually or in combination.

Scope of Problem Volume Estimates

As a result of agreements at the May 17, 2012, Core Team meeting, the scope of the problem was refined to include two volume estimates for remedial alternative development and evaluation:

1. This volume estimate includes the ash and contaminated soil media from the P-Area Ash Basin to the edge of a 30-meter (m) (100-foot [ft]) buffer established from the Dunbarton Bay and includes the former north and middle sections (see Figure 3-1). The 30-m (100-ft) buffer was established around the Dunbarton Bay to be protective

of the environment of the bay, thus preventing injury to its sensitive ecosystem. Because of the delineation of the buffer, there is no further need to reference the north or middle sections because the entire area between the PAB and edge of the buffer will be remediated. The estimate assumes 16,741 m^3 (591,187 cubic feet [ft^3] or 22,000 cubic yards [yd^3]) will be excavated and hauled to either an on-SRS or off-SRS ex situ containment facility.

Also as a result of agreements at the May 17, 2012, Core Team Meeting, the wetlands associated with Dunbarton Bay were re-delineated. The re-delineation determined the wetlands does not extend to the area described in #1 above - this area is approximately 4.9 ha (12 ac) and contains 16,820 m^3 (22,000 yd^3) of ash/soil media which is proposed to be excavated. The 30 m (100 ft) buffer is not part of the wetlands either but is used as a protective barrier to prevent damage to the actual wetland ecosystem from construction activities. Please refer to Figure 3-1.

2. This estimate includes the total volume of ash and contaminated soil media from the PAB to the farthest extent of ash migration in the Dunbarton Bay. The estimate assumes approximately 61,332 m^3 (2,165,928 ft^3 or 80,220 yd^3) will be excavated and hauled to either an on-SRS or off-SRS ex situ containment facility (Figure 3-2). The area proposed for excavation within this estimate includes a total of approximately 37 acres inclusive of the 4.9 ha (12 ac) of area not designated as wetlands and 10 ha (25 ac) which are wetlands. Please refer to Figure 3-1

3.1 Development of Remedial Alternatives

Based upon the technology screening and the RAO for the WADB, three remedial alternatives are being carried forward. All alternatives except the No Action alternative can attain the RAO. All alternatives will be combined with LUCs, except for those sub-alternatives which evaluate excavation of the total volume of ash.

3.1.1 Alternative A-1: No Action

The No Action alternative is required by the NCP to serve as a baseline for comparison with other remedial alternatives. Under this alternative, no effort would be made to control access, limit exposure, or reduce toxicity, mobility, or volume at the WADB. This alternative would leave the WADB in its current condition with no additional controls. This alternative does not include 5 year remedy reviews.

3.1.2 Alternative A-2 Land Use Controls

This alternative involves only the use of LUCs to limit access to the WADB. LUCs, which break the exposure pathway, have been implemented successfully within SRS and are fully employed in all areas of the site to limit access at the site boundary and facilities. LUCs would be implemented at the WADB by posting warning and no trespassing signs, implementation of a Land Use Control Implementation Plan (LUCIP), and deed restrictions in the event the property is ever sold. LUCs also would be applied to the location of any remaining ash deposition in the wetlands. Any additional controls could be easily applied in other regulatory documents and would be protective of the IOU on-site worker receptor. The cost of this option is considered low and effectiveness would be high to prevent human exposure. This alternative is retained for the detailed analysis.

3.1.3 Alternative A-3: Excavation Combined with Ex Situ Containment

Alternative 3 consists of four sub-alternatives which all use excavation and ex situ containment, but differ in the location of ex situ containment (on-SRS vs. off-SRS), the volume of ash and contaminated soil which is excavated, and the use of LUCs.

This alternative involves excavating the contaminated media (ash/soil) in the WADBs from the surface of the ash down to the native soil interface. Soil samples will be collected and analyzed to confirm if the RAO or SRS background concentrations have been achieved by the cleanup. A SAP which will include a sampling design as well as sample collection and analytical methods will be developed and presented in the

Corrective Measures Implementation/Remedial Action Implementation Plan (CMI/RAIP). This remedial alternative includes clearing and grubbing vegetation, road building, erosion control, grading, excavation of ash and contaminated soil, stockpiling the contaminated media, and then hauling to an approved on-SRS or off-SRS ex situ containment facility. Two of the sub-alternatives leave a 30-m (100-ft) buffer area surrounding the Dunbarton Bay and two of the alternatives evaluate excavation of the total volume of ash and contaminated soil. The 30-m (100-ft) buffer is used to protect the bay's sensitive ecosystem from further damage caused by excavation and construction activity. The excavation alternative would be extremely effective to eliminate IOU on-site worker exposure to the contaminated ash/soil media.

A description of the four sub-alternatives is listed below:

1. A-3a – Excavate all ash and contaminated soil media from the PAB border to the edge of the 30-m (100-ft) buffer around the Dunbarton Bay (approximately 16,741 m^3 [591,187 ft^3 or 22,000 yd^3]) and transport to an approved on-SRS ex situ containment facility such as the H-Area Ash Basin. This option employs LUCs since the entire volume of ash will not be removed.

2. A-3b – Excavate all ash and contaminated soil media from the P-Area Ash Basin border to the edge of the 30-m (100-ft) buffer around the Dunbarton Bay (approximately 16,741 m^3 [591,187 ft^3 or 22,000 yd^3]) and transport to an approved off-SRS ex situ containment facility such as Three Rivers Landfill. This option employs LUCs since the entire volume of ash will not be removed.

3. A-3c - Excavate total volume of ash and contaminated soil media including the Dunbarton Bay (approximately 61,332 m^3 [2,165,928 ft^3 or 80,220 yd^3]) and transport to an approved on-SRS ex situ containment facility such as the H-Area Ash Basin. This option does not employ LUCs since the entire volume of ash will be removed to support unrestricted land use.

4. A-3d - Excavate total volume of ash and contaminated soil media including the Dunbarton Bay (approximately 61,332 m^3 [2,165,928 ft^3 or 80,220 yd^3]) and transport to an approved off-SRS ex situ containment facility such as Three Rivers Landfill. This option does not employ LUCs since the entire volume of ash will be removed to support unrestricted land use.

The table below summarizes the differences between the sub-alternatives;

Alternative	Ex Situ Containment On-SRS	Ex Situ Containment Off-SRS	Waste Volume *(yd^3)*	Land Use Controls
A-3a	Yes	No	22,000	Yes
A-3b	No	Yes	22,000	Yes
A-3c	Yes	No	80,220	No
A-3d	No	Yes	80,220	No

The decision and location of the ex-situ containment facility will be documented in the ROD. The cost for all the sub-alternatives is considered to be high based upon construction cost, hauling cost, and tipping fees.

3.2 Screening of Alternatives for Effectiveness, Implementability, and Cost

In this section, the alternatives for the WADB are evaluated against the CERCLA criteria of effectiveness, implementability, and cost. Table 3-1 summarizes the results of this screening. The alternatives that are retained will be analyzed in detail in Section 4.

3.2.1 Effectiveness Criteria

For an alternative to be effective, it must achieve specified objectives, must be compatible with the contaminant characteristics and unit conditions, and must be protective of human health and the environment in the long term. The alternative must also be effective in reducing the risk to human health and the environment in the short term (during construction and construction execution). In addition, each alternative should be effective in decreasing the inherent threats or risks associated with hazardous substances or media by reducing their toxicity, mobility, or volume through treatment.

Permanence of the action is also considered. Alternatives that do not provide adequate protection of human health and the welfare of the environment or that do so to a much lesser extent than a comparable alternative are screened out and not considered during the detailed analysis.

3.2.2 Implementability Criteria

Implementability addresses both the technical and institutional feasibility of applying a technology. Under this criterion, technologies are evaluated based on the technical feasibility to construct, reliably operate, and meet technology-specific regulations for the particular treatment operation, maintenance, and monitoring of technical components of the alternative, if required, after the remedial action is complete. Institutional feasibility of an alternative refers to the ability to obtain necessary approvals and the availability of treatment, storage, and disposal services and capacity, as needed, as well as availability of specific equipment, technical specialists, and other related components.

The nature of the alternative should be such that it can be implemented in a cost effective and timely manner in the physical setting associated with the wetland. In addition, the implementation of the technology should not elicit substantial public concerns in the community. Site accessibility, available area, and potential future use of the property may affect the implementation of a specific technology. Mobilization and permitting or approval requirements must be workable and previously demonstrated at similar projects. Preliminary consideration is also given to regulatory constraints such as waste handling, disposal, and treatment requirements that would affect the implementation of a technology. These considerations will be evaluated further during the detailed analysis for retained alternatives when action-specific ARARs are developed. Alternatives are screened out and will not be considered during the detailed analysis.

3.2.3 Cost Criteria

A qualitative cost evaluation is provided so that cost comparisons can be made among the alternatives. Alternative costs are described as high, medium, or low relative to other technologies in the same general response action category (e.g., containment technologies). Qualitative evaluations take into consideration capital costs and O&M costs. These estimates are based on prior estimates, previous experience, and engineering judgment. Alternatives demonstrating comparable levels of applicability, effectiveness, and implementability as other technologies but at a significantly greater cost will be rejected. Otherwise, cost will not be used as a criterion to screen technologies at this point in the FCMS/FS process.

3.2.4 Alternative A-1: No Action

Description

Under the No Action alternative at the WADB, no remedial efforts would be made to control risk, treat or remove contaminated media, or reduce toxicity, mobility, or volume of contaminated media. LUCs and remedial actions would not be implemented. There is no 5-year remedy review. This alternative is not effective to achieve the RAOs. Implementability is not a consideration since no action would be implemented. There are no capital construction or system O&M costs for the No Action alternative. There is no cost associated with this alternative.

This alternative is retained for further analysis as required by the NCP.

3.2.5 Alternative A-2: Land Use Controls

3.2.5.1 Description

This alternative involves the use of LUCs to limit access to the area so human exposure to the contaminated media is controlled within acceptable limits for an on-site worker. Further analysis of the human health risk (human health risk appendices) provides additional data evaluation regarding the human health risk (9.9E-05) for the IOU on-site worker. Since human health risk from exposure to contaminated media is the only hazard at the WADB, LUCs can satisfactorily and independently achieve the RAO and protect the IOU on-site worker. LUCs have been implemented successfully at SRS on numerous projects and are fully employed in all areas of the site. LUCs would include posting warning and no trespassing signs, access controls, institutional controls (i.e., administrative measures) and use restrictions, deed restrictions in the event the property is ever sold, and mandatory 5-year remedy reviews. Any additional controls could be easily manipulated into the WADB and would provide further protection of the IOU on-site worker. The cost of this alternative is considered low and strict adherence to LUCs would be an effective remedial alternative.

For all alternatives that leave hazardous substances in place and pose a potential future risk, land use restrictions are required. LUCs, implemented as part of the remedial action, will be maintained until the concentration of hazardous substances in the soil and sediments are at such levels to allow for unrestricted use and exposure. A Land Use Control Implementation Plan (LUCIP) will be prepared by the USDOE that describes the implementation and maintenance actions for the interim remedial action, including periodic inspections. The USDOE is responsible for implementing, maintaining, monitoring, reporting upon, and enforcing the LUCs selected in the ROD. The LUCIP will remain in effect unless and until modifications are approved by the USEPA and SCDHEC as needed to be protective of human health and the environment. LUCIP modification will only occur through another CERCLA document.

This alternative is retained for further analysis as it is effective, can be implemented, and is cost effective.

3.2.6 Alternative A-3: Excavation Combined with Ex Situ Containment

3.2.6.1 <u>Description</u>

Alternative A-3 has four sub-alternatives which involve excavation of the contaminated media (ash/soil) from the surface of the ash down to the native soil interface. Soil samples will be collected and analyzed to confirm if the RAO or SRS background concentrations have been achieved by the cleanup. A SAP which will include a sampling design as well as sample collection and analytical methods will be developed and presented in the CMI/RAIP. Leaving a 30-m (100-ft) buffer area surrounding the Dunbarton bay would protect the bay's sensitive ecosystem from further damage caused by excavation activities. This remedial alternative would be effective to eliminate IOU on-site worker receptor exposure to the contaminated ash/soil media.

Alternative 3 has four sub-alternatives and are identified below:

1. A-3a – Excavate all ash and contaminated soil media from the PAB to the edge of the 30-m (100-ft) buffer around the Dunbarton Bay (approximately 16,741 m^3 [591,187 ft^3 or 22,000 yd^3]) and transport to an approved on-SRS ex situ containment facility such as the H-Area Ash Basin. This option employs LUCs since the entire volume of ash will not be removed.

2. A-3b – Excavate all ash and contaminated soil media from the P-Area Ash Basin to the edge of the 30-m (100-ft) buffer around the Carolina Bay (approximately 16,741 m^3 [591,187 ft^3 or 22,000 yd^3]) and transport to an approved off-SRS ex situ containment facility such as Three Rivers Landfill. This option employs LUCs since the entire volume of ash will not be removed.

3. A-3c – Excavate entire volume of ash and contaminated soil media including the Dunbarton Bay (approximately 61,332 m^3 [2,165,928 ft^3 or 80,220 yd^3]) and transport to an approved on-SRS ex situ containment facility such as the H-Area Ash Basin. This option does not employ LUCs since the entire volume of ash will be removed.

4. A-3d – Excavate entire volume of ash and contaminated soil media including the Dunbarton Bay (approximately 61,332 m^3 [2,165,928 ft^3 or 80,220 yd^3]) and transport to an approved off-SRS ex situ containment facility such as Three Rivers Landfill. This option does not employ LUCs since the entire volume of ash will be removed.

Excavation and ex situ containment are some of the most aggressive types of remedial actions. While no treatment is involved, the contaminated media is removed and disposed in an approved ex situ containment facility either on-SRS or off-SRS. Excavation and ex situ containment of the contaminated media will significantly reduce the, mobility, and mass of ash/soil media at WADB since they are permanently removed from the waste unit and safely interred in an approved disposal facility. Human health and the environment are protected in the long term, so the remedial alternative is effective.

The technical and institutional feasibility of implementing this alternative is high. Savannah River Site (SRS) has significant experience in earth moving and containment of ash. Previous excavation and containment of ash at the P- and R-Area Ash Disposal Basins were both successful and final RODs have are approved for both these facilities. All sub-alternatives are considered to have high cost since the ash must be excavated, hauled a distance to an approved containment facility, and in sub-Alternatives A-3b and A-3d, tipping fees may be imposed.

This alternative is retained for further analysis.

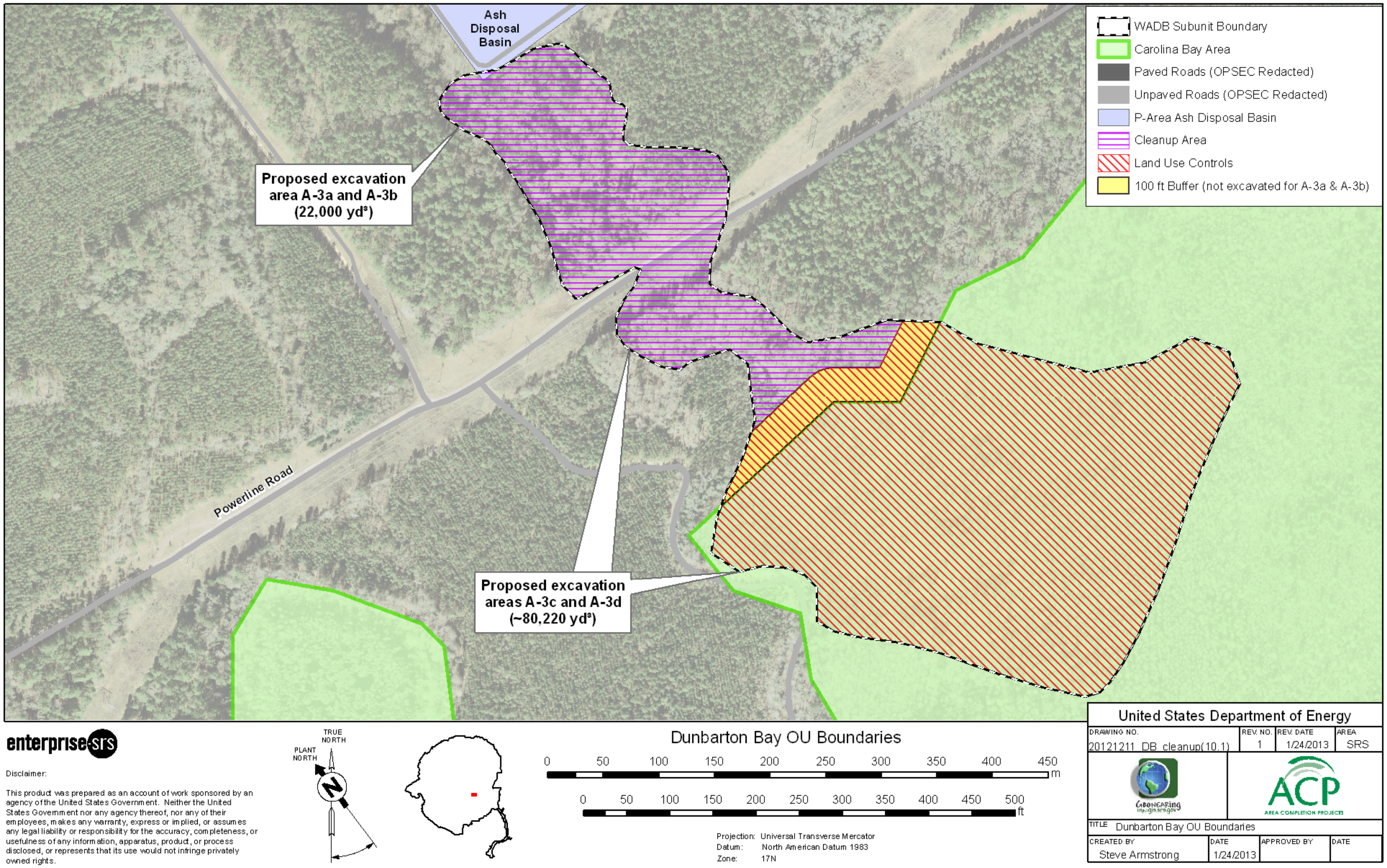

Figure 3-1. Ash to be Excavated and Showing LUCs Around WADB Subunit

Table 3-1 Summary of Alternative Screening for Wetland Area at Dunbarton Bay Subunit

Alternative	Effectiveness	Implementability	Cost	Status	Comments
A-1 - No Action	Not effective in preventing exposure of IOU on-site worker to contaminated media. Alternative does not treat waste.	Not applicable	None	Required	Alternative is required by NCP
A-2 - Land Use Controls	Effective for achieving RAOs; prevents exposure of IOU on-site worker. Does not reduce toxicity, mobility, or volume of waste	Already implemented at SRS; additional measures to be incorporated into Site Use/Site Clearance permits, SSHASPs to protect on-site worker	Low	Retained	Effective; implementation would allow contaminated media to remain in place where exposure scenarios are still a possibility
A-3a	More effective in reducing risk to on-site worker. Permanently reduces volume, toxicity and mobility of waste by 22,000 yd^3; combined with LUCs	Can be implemented using standard earth-moving equipment. Successfully implemented at SRS for P Ash Basin.	High	Retained	Protective of human health; portion of ash permanently removed from wetland reducing risk, volume, toxicity, and mobility; Protects wetlands and sensitive ecosystem of Dunbarton Bay
A-3b	More effective in reducing risk to on-site worker. Permanently reduces volume, toxicity and mobility of waste by 22,000 yd^3; combined with LUCs	Can be implemented using standard earth-moving equipment. Successfully implemented at SRS for P Ash Basin.	High	Retained	Protective of human health; portion of ash permanently removed from wetland reducing risk, volume, toxicity, and mobility; Optimally protects wetlands and sensitive ecosystem of Dunbarton Bay
A-3c	Most effective in reducing risk to on-site worker. Permanently reduces volume, toxicity and mobility of waste 80,220 yd^3	Can be implemented using standard earth-moving equipment. Successfully implemented at SRS for P Ash Basin.	High	Retained	Protective of human health; all ash would be removed from WADB reducing risk, volume, toxicity, and mobility; greatest negative impact to the environment and causes more destruction of the Bay than any of the other sub-alternatives
A-3d	Most effective in reducing risk to on-site worker. Permanently reduces volume, toxicity and mobility of waste 80,220 yd^3	Can be implemented using standard earth-moving equipment. Successfully implemented at SRS for P Ash Basin.	High	Retained	Protective of human health; all ash would be removed from WADB reducing risk, volume, toxicity, and mobility; greatest negative impact to the environment and causes more destruction of the Bay than any of the other sub-alternatives

4.0 DETAILED ANALYSIS OF ALTERNATIVES

Based upon the technology screening and the remedial action objective (RAO) for the Wetland Area at Dunbarton Bay (WADB), three remedial alternatives including four sub-alternatives are being carried forward into Chapter 4 for detailed alternatives analysis.

All alternatives except the No Action alternative can attain the RAO. All alternatives will be combined with LUCs, except for those alternatives which evaluate excavation of the total volume of ash. These remaining alternatives will be evaluated against the nine CERCLA criteria listed in the NCP.

4.1 Detailed Analysis of Alternatives

The NCP [40 CFR 300.430(e) (91)] requires that potential remedial alternatives undergo detailed analysis using relevant criteria that will be used by decision makers to select a final remedy. The results of the detailed analysis are then examined to compare alternatives and identify key tradeoffs among alternatives.

The Natural Resource Injury Evaluation (NRIE) Checklist and supporting descriptions are provided in Appendix G. The purpose of the NRIE Checklist is to identify potential natural resource injuries associated with CERCLA remedial activities. Based on the NRIE Checklist, natural resources in the locale have been impacted by hazardous substances from the unit. Remedial alternatives under consideration may or may not address injuries to the natural resources. Remedial alternatives considered may cause additional injury based on the scope of the action (e.g., excavation within the Carolina Bay). No irreversible or irretrievable resource losses are known to exist.

Although a comparative analysis of alternatives is provided in this FCMS/FS report, this document does not propose a preferred alternative. The preferred alternative will be presented in the Statement of Basis (SB)/Proposed Plan (PP). The preferred alternative will be based on information contained in this report and comments received from USEPA, SCDHEC, and the public prior to finalization in the ROD.

4.1.1 Introduction to Alternatives Selection

In this section, the alternatives formulated and retained are evaluated in detail against CERCLA requirements. The statutory requirements that guide the evaluation of remedial alternatives under CERCLA state that a remedial action must:

- Be protective of human health and the environment
- Attain ARARs or define criteria for invoking a waiver
- Be cost effective
- Use permanent solutions to the maximum extent

USEPA has established nine evaluation criteria to address these statutory requirements under CERCLA. The criteria fall into the categories of threshold criteria, primary balancing criteria, and modifying criteria. Modifying criteria (i.e., State or support agency acceptance and community acceptance) will be evaluated after the public comment period on the SB/PP. Evaluation criteria categories and the nine evaluation criteria are listed and explained in the following sections.

The CMS criteria are similar to the NCP criteria, with the exception of a CMS criterion that specifies the attainment of media protection standards. The media protection standards are not promulgated and therefore, will not be addressed in this combined report.

4.1.1.1 Threshold Criteria

Each alternative must meet the following threshold criteria to be selected as a permanent remedy under CERCLA:

1. **Overall protection of human health and the environment** – The overall protection of human health and the environment is evaluated for each alternative on the basis of how the alternative reduces the risk of exposure to contaminants from potential exposure pathways through engineered barriers or LUCs. Each alternative is

examined as to whether it creates any unacceptable short-term risks to human health. In addition, the RCRA criterion specifying control of source releases is evaluated.

2. **Compliance with ARARs** – Remedial actions under CERCLA must attain all ARARs. ARARs are cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal, State, or local environmental law that specifically addresses a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. Three types of ARARs (chemical, action, and location-specific) have been developed to simplify identification and compliance with environmental requirements. Location-specific ARARs were evaluated to determine applicability to the combined report.

4.1.1.2 Primary Balancing Criteria

Primary Balancing criteria are factors that identify key tradeoffs among alternatives.

3. **Long-term Effectiveness and Permanence** – Long-term effectiveness and permanence are evaluated for each alternative on the basis of the magnitude of residual risk and the adequacy and reliability of controls used to manage contaminated media that remain after response objectives have been achieved. Alternatives that offer long-term effectiveness and permanence halt or otherwise mitigate any potential for offsite contaminant transport and minimize the need for future engineered controls. The degree of uncertainty with regard to treatment effectiveness is also evaluated.

4. **Reduction of Mobility, Toxicity, or Volume through Treatment** – The statutory preference is to select a remedial action that employs treatment to reduce the toxicity, mobility, or volume of hazardous substances. The degree to which alternatives employ recycling or treatment is assessed, including how treatment is used to address the principal threats posed by the waste unit.

5. **Short-term Effectiveness** – Evaluation of alternatives for short-term effectiveness takes into account protection of remedial workers, members of the community, and the environment during implementation of the remedial action and the time required to achieve RAOs/RGOs. Schedule estimates are based on projected availability of materials and labor and may have to be updated at the time of remediation.

6. **Implementability** – Each alternative is evaluated with respect to the technical and administrative feasibility of implementing the alternatives as well as the availability of necessary equipment and services. This criterion includes the ability to obtain services, capacities, equipment, and specialists necessary to construct components of the alternative; the ability to operate the technologies and monitor their performance and effectiveness; and the ability to obtain necessary approvals from other agencies.

7. **Cost** – Accuracy of present-worth costs is +50/-30 percent according to USEPA guidance. Detailed cost estimates are derived from current information including vendor quotes, conventional cost estimating guides (e.g., Mean Site Work Cost Data), and costs associated with serial costs, site conditions, competitive market conditions, final project scope, and implementation schedule at the time that the remedial activities are initiated. Real interest rates on U.S. Treasury notes and bonds of specific maturity were used to estimate present-worth costs. Present worth costs for review of the site remedy every five years are given for each alternative for which residuals remain at the site. Present-worth costs for these items are based on an estimated time frame of operation. Cost estimates are presented in Appendix F.

4.1.1.3 Modifying Criteria

Modifying criteria (i.e., State or support agency acceptance, community acceptance) will be considered during remedy selection.

8. **State or Support Agency Acceptance** – The preferred alternative should be acceptable to State and support agencies. The State acceptance criterion is evaluated based on scoping meetings held between USDOE, USEPA, and SCDHEC, and based

on comments received on this FCMS/FS and are addressed in the final SB/PP document.

9. **Community Acceptance** – The concerns of the community should also be considered in presenting alternatives that would be acceptable to the community. Community acceptance is evaluated based on comments on the SB/PP received during the public comment period. These comments are considered in the final remedy selection for the ROD and the issuance of a RCRA permit modification.

4.1.2 Analysis of Alternatives

The purpose of source control corrective measures/remedial alternatives for the WADB is to address ash and contaminants in soils that exceed risk thresholds and to address the RAOs of the waste unit. The following alternatives are considered:

Alternative	Remedial Action Description
Alternative A-1	No Action (no cost)
Alternative A-2	Land Use Controls • Engineering • Administrative (restricted access) • Warning/No Trespassing Signs • LUCIP • Deed Restrictions • Work Clearance Permit Procedures
Alternative A-3a	Excavate all ash and contaminated soil media from the PAB to the edge of the 100 buffer around Dunbarton Bay (approximately 16,741 m^3 (591,187 cubic feet [ft^3] or 22,000 cubic yards [yd^3]) and transport to an approved on-SRS ex situ containment facility such as the H-Area Ash Basin. This option employs LUCs since the entire volume of ash will not be removed.
Alternative A-3b	Excavate all ash and contaminated soil media from the PAB to the edge of the 100 buffer around the Bay (approximately 16,741 m^3 [591,187 yd^3 or 22,000 yd^3]) and transport to an approved off-SRS ex situ containment facility such as Three Rivers Landfill. This option employs LUCs since the entire volume of ash will not be removed.
Alternative A-3c	Excavate entire volume of ash and contaminated soil media including the Bay (approximately 61,332 m^3 (2,165,928 ft^3 or 80,220 yd^3) and transport to an approved on-SRS ex situ containment facility such as the H-Area Ash Basin. This option does not employ LUCs since the entire volume of ash will be removed.
Alternative A-3d	Excavate entire volume of ash and contaminated soil media including the Bay (approximately 61,332 m^3 [2,165,928 ft^3 or 80,220 yd^3]) and transport to an approved off-SRS ex situ containment facility such as Three Rivers Landfill. This option does not employ LUCs since the entire volume of ash will be removed.

Detailed analysis of these alternatives is presented below and summarized in Table 4-1.

4.1.2.1 Introduction to Alternative Analysis

All of the WADB alternatives will be evaluated against the nine CERCLA evaluation criteria that provide the basis for evaluating the alternatives and selecting a remedy. The purpose of this section is to identify key advantages and disadvantages of each alternative evaluated for the WADB in relation to the two threshold and five balancing criteria. The remaining two analyses and modifying criteria and will be determined in the SB/PP. The results of the evaluation are discussed below.

4.1.2.2 Individual Analyses of the Alternatives for WADB

Alternative A-1 – No Action

Alternative A1 consists of performing no action to address contamination at the WADB. Contaminated media would remain in place and no engineered or institutional controls or active remediation would be conducted to control future potential risk to the IOU on-site worker; to treat or remove contaminated media; or to reduce toxicity, mobility, or volume of the contaminated media. There is no 5-year remedy review.

Overall Protection of Human Health and the Environment

The No Action alternative would not address potential risk to the IOU on-site worker from exposure to the ash or contaminated soil in the WADB. This alternative does not reduce risk to human health or the environment.

Compliance with ARARs

Chemical-Specific ARARs: No chemical-specific ARARs are associated with the No Action alternative.

Location–Specific ARARs: No location-specific ARARs are associated with the No Action alternative.

Action-Specific ARARs: No action-specific ARARs are associated with the No Action alternative.

Long-Term Effectiveness and Permanence

Residual risk to human health under future conditions at the WADB would remain unchanged under the No Action alternative. Risk to the environment would be unchanged from the current risk of 9.9E-05 for the IOU on-site worker. This alternative does not provide for long-term effectiveness or permanence.

Reduction of Toxicity, Mobility, or Volume through Treatment

Active treatment or removal of contaminated media to reduce toxicity, mobility, or volume is not associated with the No Action alternative; therefore, there is no reduction in the toxicity, mobility or volume of ash or soil contaminants in the wetland.

Short-Term Effectiveness

The No Action alternative would not endanger the surrounding communities or remedial workers or adversely affect the environment.

Implementability

Since this alternative requires no action, implementability is not a consideration.

Cost

There is no present-worth cost estimated for the No Action alternative since there is no action implemented and no 5-year remedy review. Detailed cost estimates are provided in Appendix F. A summary of the estimates cost is below.

Total Present-Worth Cost *$0*

Alternative A-2 – Land Use Controls

Alternative A-2 involves the use of LUCs to limit access to and limit the use of the contaminated portion of the wetland so human exposure to the ash is controlled within acceptable limits for the IOU on-site worker. This alternative does not remove or eliminate receptor exposure potential by removal or treatment of hazardous substances – only exposure is controlled. Through administrative and engineering controls, work activities would be limited and controlled by the use of work clearance permits and personal protection equipment throughout the area of contamination. The LUCs alternative would restrict access to, contact with, and excavation of the contaminated media. Warning/no trespassing signs would be posted informing personnel not to enter the posted area to prevent contact with hazardous substances. The use of LUCs can prevent the current and future IOU on-site worker from being exposed to hazardous substances in the ash and contaminated soil.

Because there is no excavation, treatment, or removal of ash or contaminated soil media in Alternative 2, LUCs will be needed to control access and land use for the entire area where ash has been deposited. In the case of Alternative 2, LUCs will cover an estimated 15.0 ha (37 ac) and need to be in effect for an estimated 200 years.

Overall Protection of Human Health and the Environment

The exposure pathway is broken by controlling access to and use of the contaminated wetlands by preventing exposure of the on-site worker and any other human health receptors. This alternative does not remove or treat any contaminants; however, the application of LUCs does prohibit unrestricted use and access to the wetland unless authorized by the issuance of valid work clearance permit which establishes safe working conditions and control of the work activities. Even though the ash and contaminated soil is not removed under this alternative and the risk remains unmitigated, LUCs, which include engineering and institutional controls, can be effective to protect human health receptors by breaking the exposure pathway.

Compliance with ARARs

Chemical-Specific ARARs:	No chemical-specific ARARs are associated with Alternative A-2.
Location-Specific ARARs:	No location-specific ARARs are associated with Alternative A-2.
Action-Specific ARARs:	No action-specific ARARs are associated with Alternative A-2.

Long-Term Effectiveness and Permanence

The long-term effectiveness for protecting human health can be achieved under this alternative as long as unit-specific LUCs are maintained. Risks are prevented by controlling access to and use of the contaminated area by preventing exposure of the on-site worker and any other human health receptors. LUCs, implemented as part of a remedial action, will be maintained until the concentration of hazardous substances in the ash/soil is at such levels to allow for unrestricted use and exposure. A LUCIP will be prepared by the USDOE that describes the implementation and maintenance actions for the interim remedial action, including periodic inspections. The USDOE is responsible for implementing, maintaining, monitoring, reporting upon, and enforcing the LUCs. The LUCIP will remain in effect unless and until modifications are approved by the USEPA and SCDHEC as needed to be protective of human health and the environment. LUCIP modification will only occur through another CERCLA document.

The timeframe for LUCs is estimated for a 200-year duration. The contaminants can be long-lived and there is no treatment or excavation of contaminated media so residual risk exceeds 1E-06 or exceeds SRS background concentrations. Remedy reviews will be performed every 5 years for a total of 40 reviews. Annual inspections will be performed to ensure warning and no trespassing signs are in place and no encroachment onto the controlled area is occurring. Signs will be replaced and/or repaired as needed and records for site use/site control permits will be maintained within the SRS infrastructure.

Since the WADB subunit is within the SRS boundary, the reliability of access control should be high.

Reduction of Toxicity, Mobility, or Volume Through Treatment

No active treatment systems are associated with the LUCs alternative that would reduce the toxicity, mobility, or volume of hazardous substances in the wetland. This alternative prevents receptor exposure to the contaminants through controlled access and limiting use.

Short-Term Effectiveness

This alternative poses no risk to IOU on-site workers or the community because no work will be performed which disturbs the ash in the wetland. All of the ash and contaminated soil media are within an area with restricted access; therefore, it is not accessible to members of the public or community. There is no hazard to nearby communities since there are none in proximity.

Implementability

LUCs are currently active in all areas of SRS. LUCs have been implemented at many waste units at SRS including the P and R-Area Ash Basin Disposal Facilities. The implementation of LUCs presents no technical or administrative impediments.

Cost

Costs for LUCs are considered minimal. Costs associated with this alternative include posting 90 warning signs around the perimeter of the wetland where the ash/soil is located as well as SRS institutionally controlling access to the wetland by Site Infrastructure with the Site Use/Site Control permit system. A review of the remedy will be performed every five years for at least 200-year duration. A summary of the estimated present-worth cost is presented below:

Total Capital Cost *$115,362*

Present-Worth O&M Cost *$1,708,737*

Total Estimated Cost *$1,824,099*

Alternative A3 – Excavate Contaminated Media and Haul to an Approved Ex Situ Disposal Facility

Alternative 3 consists of four sub-alternatives which all use excavation combined with ex situ containment, but differ in the location of ex situ containment (on-SRS versus off-SRS), volume of ash and contaminated soil which is excavated, and use of LUCs (refer to following table). The extent of property under land use controls will vary by sub-alternative. Sub-alternatives A-3a and A-3b will place approximately 10 ha (25 ac) of property under land use controls. However, since sub-alternatives A-3c and A-3d propose excavation and ex situ containment of the entire volume of ash and contaminated soil, no land use controls will be required for these alternatives.

Alternative	Ex Situ Containment On-SRS	Ex Situ Containment Off-SRS	Waste Volume *(yd^3)*	Land Use Controls
A-3a	Yes	No	22,000	Yes/25 acres
A-3b	No	Yes	22,000	Yes/25 acres
A-3c	Yes	No	80,220	No/0 acres
A-3d	No	Yes	80,220	No/0 acres

Overall Protection of Human Health and the Environment

All the sub-alternatives protect human health and the environment by excavating contaminated media and hauling it for disposal to an approved off-unit containment facility at a location away from the wetland. The sub-alternatives would be protective of human health and achieve RAOs in a short period (several months) of time. These alternatives are more protective of the environment than any of the other alternatives since contaminated media is permanently removed and safely interred away from the wetland. Under sub-Alternatives A-3a and A-3b, risk posed by the ash/soil remaining inside the Dunbarton Bay and buffer area (~44,497 m^3 [~58,220 yd^3]) is greatly reduced since the volume of ash and contaminated soil will be reduced by

16,820 m^3 (22,000 yd^3). Additionally, Alternative A-2, LUCs, is combined with sub-Alternatives A-3a and A-3b to prevent any receptor exposure to the residual ash/soil media in the Dunbarton Bay. Sub-alternatives A-3a and A-3b are also more protective of the environment because ash located in ecologically non-sensitive areas will be removed, while ash located within the Dunbarton Bay will not be excavated, thus preventing damage to the sensitive ecosystem of the bay.

Alternatives A-3c and A-3d proposes excavating the total 61,332 m^3 (80,220 yd^3) of ash and contaminated media, including that in the Dunbarton Bay and buffer area, and hauling it for disposal to an approved off-unit containment facility at a location away from the wetland. These excavation and ex-situ containment remedial alternatives are the most aggressive contaminant removal actions. Removal of all the contaminated ash and soil media will reduce receptor risk to less than 1E-06 or SRS background concentrations. Because all the ash and contaminated media are removed at the WADB subunit, there is not a need for land use controls. However, Alternatives A-3c and A-3d also cause the greatest magnitude of destruction to the sensitive ecosystem of the Dunbarton Bay.

Compliance with ARARs

Chemical-Specific ARARs: None.

Location-Specific ARARs: There is a probability that location-specific ARARs will be associated with the excavation of the ash/soil media. Any excavation within any wetland area in/or around the Dunbarton Bay may require restoration upon completion of the excavation to comply with the applicable ARARs in 10 CFR 1023 (see Table 2-2). Action will need to be taken to avoid, minimize, or mitigate the destruction, loss, or degradation of wetlands.

Action-Specific ARARs: In order to minimize erosion of sediment and manage storm water runoff that may occur during the remedial actions, a storm water management plan would be required to comply with SC R. 61-9.122,41 (see Table 2-2).

In addition, the disposal and transportation of waste generated from Alternative 3 would be handled in accordance with Federal and State regulations 40 CFR 262.11(b) and SCDHEC 61-107.5(D)(3) (see Table 2-2).

Ex situ containment of the contaminated ash/soil media will also trigger South Carolina SC R-61-107 requirements which require ash disposal in a properly constructed and permitted disposal facility. This requirement can be attained through use of an existing and approved on-SRS facility or transporting the contaminated media to an approved off-SRS facility such as Three Rivers Landfill. SRS will cooperate with the SCDHEC to ensure compliance with this ARAR.

Long-Term Effectiveness and Permanence

All sub-alternatives permanently remove and safely dispose of some quantity of contaminated soil from WADB and therefore, offer long-term protection. All the sub-alternatives are more effective than alternative A-2, LUCs, as a "stand alone" alternative since ash and contaminated soil media is removed from the WADB subunit and safely contained in an approved disposal facility.

Sub-alternatives A-3a and A-3b propose to remove ~16,820 m^3 (~22,000 yd^3) of ash and contaminated soil media which will leave ~44,497 m^3 (~58,220 yd^3) of ash in the Dunbarton Bay and buffer area. Residual risk will be reduced by these sub-alternatives but will also leave some residual risk in the Dunbarton Bay and buffer area. Because some residual contamination will remain after implementation of these sub-alternatives, approximately 10 ha (25 ac) of the subunit will require land use controls for an estimated 200-year duration. Also, because there will be residual risk, 5-year remedy reviews will be required for the estimated 200 year duration as well.

Reduction of Toxicity, Mobility, or Volume Through Treatment

None of the sub-alternatives employ treatment of hazardous substances. However, excavation and ex situ containment will reduce mobility and volume of the contaminated media at WADB by removing it and safely disposing the ash/soil in an approved ex situ containment facility.

Short-Term Effectiveness

The four sub-alternatives pose no significant risk to the community or workers. Remedial workers will have the greatest risk of exposure during excavation and hauling activities. Best management construction practices will be utilized to minimize any risk to surrounding communities or workers while activities are performed at the wetland.

Even though remedial workers would potentially be exposed to more contamination for sub-alternatives A-3c and A-3d compared to A-3a and A-3b, strict adherence to the project-specific health and safety plan will prevent exposure of workers to hazardous substances.

There is no community close enough to WADB to be impacted by construction activities, since the remedial action will occur well within the institutionally controlled boundary of SRS where the public access is restricted.

Because excavation and removal of ash and contaminated soil media is only partial and will not occur in a designated wetland, sub-alternatives A-3a and A-3b will not disturb, destroy, or negatively impact the sensitive ecosystem of the Dunbarton Bay and the buffer area. The buffer area is present to provide a barrier where construction activities will stop and be mitigated, thus preventing negative impact to and protecting the Dunbarton Bay from sedimentation, erosion, and destruction of flora and fauna.

Alternatively, sub-alternatives A-3c and A-3d propose to excavate and remove the entire 61,332 m^3 (80,220 yd^3) of ash and contaminated soil media from WADB subunit. These sub-alternatives (while being the most effective for reducing receptor risk) are also the most destructive to the environment. In order to implement sub-alternatives A-3c and A-3d, it will require clear cutting all the vegetation and mature trees, cutting and building temporary roads to provide access for heavy construction equipment, construction of temporary ash and contaminated soil staging areas, and excavation and removal of soil and ash in and around the Dunbarton Bay. The construction activities needed to implement A-3c and A-3d will virtually destroy that part of Dunbarton Bay as a natural resource. The construction activity and level of destruction to the Dunbarton Bay is an unavoidable impact of implementing these two sub-alternatives. Due to the volume and location of the ash and contaminated media, there is no other feasible method or technology to cost-effectively accomplish the excavation without causing extensive and possibly irreversible destruction of part of Dunbarton Bay.

Implementability

Excavation and ex situ containment for sub-alternatives A-3a and A-3b are readily implemented with standard earth-moving equipment, materials, and conventional construction methods. The experience, knowledge, and equipment are readily available to implement these sub-alternatives. SRS has recent successful experience with excavation and disposal of ash at the P-Area Operable Unit. Therefore, there are no institutional or technical impediments.

Conversely, sub-alternatives A-3c and A-3d may not be readily implemented or there may be difficulty associated with the permitting and construction because of the wetlands. Working conditions in a designated wetlands will be more restrictive to mitigate damage from construction and more costly to restore damage caused by the construction. Additionally for sub-alternatives A-3c and A-3d, if heavy precipitation should occur prior to or during the construction period it may cause construction activities to be significantly delayed or cease because Dunbarton Bay has the potential to accumulate precipitation.

Permits for implementing sub-alternative A-3a (and A-3c as well) could be difficult to obtain and may cause delays in the project schedule. A-3a would require both the engineering and construction of an ex situ containment facility which would have to meet the requirements of South Carolina solid waste disposal facility regulations. The detailed costs for an approved solid waste disposal facility are not included in the WADB cost estimates since these are beyond the scope and funding of the WADB project. However, a preliminary estimate of the costs has been made and due to the uncertainty of regulatory and engineering requirements, costs are estimated between $1.5 and $10 million to engineer and construct an approved facility. The approved solid waste facility costs would need to be added to the cost of A-3a. If an existing facility (such as the ash basin in H-Area) were used it would require the cancelation of the existing Industrial Wastewater Permit and the application and approval of a new solid waste disposal facility permit. The permit impediments and engineering and construction activities for the permit for such a facility would outweigh the cost advantage of on-SRS disposal and would not align with project schedule milestones. For these reasons there are significant impediments for obtaining the appropriate permits for this alternative.

Permits for implementing sub-alternative A-3b should not be difficult to obtain. A-3b proposes excavation of ash/soil media from 4.9 ha (12 ac) of non-wetland area and ex situ containment of the waste in a currently permitted facility such as Three Rivers Landfill. This alternative offers the least resistance to delays or impediments caused by obtaining or changing permits and offers the greatest certainty of an approved waste disposal pathway. For this alternative excavated waste can be hauled directly to a pre-permitted facility, avoiding delays for permit issues and allowing the project to stay on schedule. Therefore, A-3b has a distinct advantage of maintaining schedule, avoidance of permitting impediments, and additional cost for the engineering and construction of an approved solid waste disposal facility.

Alternatively, permits for implementing sub-alternatives A-3c and A3d may impose both impediments and delays to implementation. While work performed under these sub-alternatives also use standard earth working and earth moving methods, the work will be performed in a designated wetland; thereby, increasing the complexity and length of time to obtain the appropriate permits.

Additionally construction may be exceedingly difficult to implement for A-3c and A-3d which proposes work in the wetlands itself. If there is heavy precipitation during the construction period, the wetland has a distinct possibility of flooding or accumulating water in the depression of the Dunbarton Bay. Wet conditions in Dunbarton Bay could potentially cause excavation activities to halt and/or cause unusually high destruction of the wetland itself.

The time required to implement alternative A-2 is 6 months. The time to implement sub-alternatives A-3a (not including time for engineering and constructions of an approved solid waste disposal facility) and A-3b is 12 months and the time to implement sub-alternatives A-3c (not including time for engineering and constructions of an approved solid waste disposal facility) and A-3d is 18 months.

Cost

Cost estimates consist of capital costs for construction, equipment, hauling costs, tipping fees and permit or licensing fees. Present worth or present value costs include cost for post-construction annual operation and maintenance cost. Present worth costs include the costs for ongoing inspections, maintenance, and 5-year remedy reviews.

An analysis is used to calculate present worth costs. The present worth analysis is used to evaluate expenditures that occur over different time periods by discounting all future costs to a common base year, usually the current year. This allows the cost of remedial action alternatives to be compared on the basis of a single figure representing the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned duration.

The present worth analysis for WADB subunit is based on an estimated duration of 200 years for land use controls for sub-alternatives A-2, A-3a, and A-3b and 2 years for sub-alternatives A-3c and A-3d. Discount rates are based on Office of Management and Budget Circular No. A-94, Appendix C.

Construction costs for the sub-alternatives would include clearing and grubbing, road building, erosion control, excavation, hauling costs, road construction, and surveying. Tipping fees for sub-alternatives A-3b and A-3d are also included.

Cost-Type	A-2	A-3a*	A-3b	A-3c*	A-3d
Total Estimated Capital Cost	$115,362	$6,566,642	$9,826,409	$12,949,158	$21,324,526
Total Present-Worth O&M Cost	$1,708,737	$$1,708,736	$1,708,737	$98,670	$98,670
Total Estimated Cost	$1,824,099	$8,275,378	$11,535,146	$13,055,204	$21,428,462

*Does not include costs associated with On-SRS containment facility (i.e., preparation, engineering permitting, or receiving waste). Estimates range between $1.5 to $10 million additional costs.

4.1.3 Comparative Analysis of Alternatives

The purpose of this section is to identify key advantages and disadvantages of each alternative relative to one another and in relation to the two threshold criteria and five balancing criteria. Emphasis is placed on the two threshold criteria – overall protection of human health and the environment and compliance with ARARs. However, key tradeoffs between alternatives are identified through comparative evaluation against the five primary balancing criteria: long-term effectiveness and permanent reduction of toxicity, mobility, or volume through treatment, short-term effectiveness, implementability, and cost. The five primary balancing criteria were assigned subjective values to aid in performing the comparative analyses. The final two modifying criteria – State or support agency acceptance and community acceptance – will be evaluated following the public comment period for the SB/PP document.

4.1.3.1 Introduction to Identification of Key Advantages and Disadvantages

All of the alternatives have been evaluated against the seven CERCLA evaluation criteria that provide the basis for evaluating the alternatives and selecting the remedy. The purpose of this section is to identify key advantages and disadvantages of each alternative evaluated relative to one another and in relation to the two thresholds and five balancing criteria.

4.1.3.2 Comparative Analysis of the WADB Alternatives

Comparative analysis of these alternatives is present below and in Table 4-2.

Overall Protection of Human Health and the Environment

With the exception of the No Action alternative, Alternative A-2 and sub-Alternatives A-3a, A-3b, A-3c, and A-3d are all protective of human health and the environment and each can achieve the RAO. Alternative A-2 provides for LUCs to prevent exposure to metallic and natural radionuclide contaminants in the ash/soil media. With rigorous adherence to the LUCs this alternative is protective of the IOU on-site worker, but would leave all hazardous substances in place. Residual risk would still exceed 1E-06 or SRS background concentrations.

Sub-Alternatives A-3a, A-3b, A-3c, and A-3d are all more protective of the IOU on-site worker than Alternative A-2 because a portion or all of the ash/soil media is excavated from the WADB subunit and/or wetland and interred in an approved and permitted ex situ containment facility. Sub-Alternatives A-3c and A-3d are even more protective of the IOU on-site worker than sub-Alternatives A-3a and A-3b since all 61,332 m^3 (80,220 yd^3) of the ash and contaminated soil is removed from the WADB including the Dunbarton Bay leaving no hazardous substances in place.

However, sub-Alternatives A-3a and A-3b have the advantage for the protection of the environment since construction activities will not occur within the 100 foot buffer around the Dunbarton Bay and will prevent damage and destruction of the sensitive ecosystem of the bay. Therefore, sub-Alternatives A-3a and A-3b will provide better protection of the environment. Sub-Alternatives A-3a and A-3b excavated 16,820 m^3 (22,000 yd^3) of ash/soil media and are combined with LUCs to prevent IOU on-site worker exposure to hazardous substances remaining in the Dunbarton Bay as a mitigating control.

Compliance with ARARs

Chemical-Specific ARARs: Because there is no excavation, treatment, or removal of ash or contaminated soil media in Alternative 2, and only LUCs are used to control access and land use for the entire area where ash has been deposited, no chemical-specific ARARs have been identified.

Location-Specific ARARs: Alternative 2 does not have to comply with any location-specific ARARs because there is no excavation, treatment, or removal of ash or contaminated soil media in Alternative 2, and only LUCs are used to control access and land use for the entire area where ash has been deposited.

Most importantly, sub-Alternatives A-3c and A-3d will have the potential to trigger and need to comply with a variety of rules and regulations to perform work in a designated wetland. If this becomes necessary, the appropriate permits will need to be applied for and approved prior to the commencement of any construction.

Since a portion of the ash is located in a designated wetland (Dunbarton Bay), compliance with the substantive requirement of the Clean Water Act (CWA), will be required. Section 404 states: "no activity that impacts waters of the United States shall be permitted if a practical alternative that has less adverse impacts exist. If there is not another viable alternative, the impacts to the wetlands must be mitigated." Leaving a 30-m (100-foot [ft]) buffer around the Carolina Bay should provide a practical alternative to avoid impacts to the wetland. Sub-Alternatives A-3a and A-3b have the advantage since construction would not be performed in the designated wetland and would be more complaint with this ARAR than either sub-Alternatives A-3c and A-3d which would be the most destructive to the wetlands.

Action-Specific ARARs: Alternative 2 does not have to comply with any action-specific ARARs since hazardous substances are not being generated, transported, or disposed.

Sub-Alternatives A-3a, A-3b, A-3c, and A-3d could trigger various federal and South Carolina regulations if an on-SRS ash disposal facility is constructed and for the characterization and disposal of solid waste and/or hazardous waste (if any). Please refer to Table 2-2 for a potential list of ARARs. Non-hazardous, non-radioactive solid waste could be sent to an on-SRS landfill. Non-hazardous, non-radioactive solid waste could be sent to the regional municipal solid waste landfill. Hazardous waste would need to be sent to a disposal facility approved for disposal of hazardous waste or meet the appropriate ARARs for design and construction of such a landfill. Sub-Alternatives

A-3a, A-3b, A-3c, and A-3d will need to comply with South Carolina Hazardous Waste Management Regulation (SC R61-79) and Identification of and Listing of Hazardous Waste (40 CFR 261) will be followed. Remedial waste characterization prior to disposal will determine if there are any additional RCRA hazardous waste storage and disposal requirements triggered under 40 CFR Parts 262, 264, and 268.

Long-Term Effectiveness and Permanence

With the exception of the No Action alternative, all alternatives provide long-term effectiveness and permanence.

For Alternative A-2, LUCs are estimated to be maintained for a 200 year duration or as long as hazardous substances remain in place. Warning/no trespassing signs would be posted informing personnel not to enter the posted area to prevent contact with hazardous substances. The use of LUCs can prevent the current and future IOU on-site worker from being exposed to hazardous substances in the ash and contaminated soil. LUCs will prevent receptor exposure due to any residual ash remaining in the wetland after excavation and ex situ containment. Alternative A-2 is not a permanent remedy because the ash/soil media would remain in situ. The magnitude of residual risk would still exceed 1E-06 or SRS background concentrations, all 15 ha (37 ac) of the WADB would require LUCs, and 5-year remedy reviews would be required for 200 years.

Sub-Alternatives A-3a and A-3b provide better effectiveness and permanence than is attainable with Alternative 2 by itself because these alternatives excavate ~16,820 m^3 (~22,000 yd^3) of contaminated ash/soil media. The magnitude of residual risk is less than 1E-06 or SRS background concentrations within the removal area, but greater than 1E-06 or SRS background concentrations in Dunbarton Bay. Because residual ash remains in Dunbarton Bay, 10 ha (25 ac) of property will required land use controls with 5 year remedy reviews required for 200 years.

A-3c and A-3d provide the best effectiveness and permanence than is attainable with all the previous alternatives. These sub-alternatives will permanently remove all of the ash and contaminated soil from the WADB subunit including the designated wetlands and dispose it safely in an approved ex situ containment facility. As such there will be no need for LUCs or 5-year remedy reviews and land use will be unrestricted.

Reduction of Toxicity, Mobility, or Volume Through Treatment

The No Action alternative would not provide any reduction in toxicity, mobility or volume of contaminants through treatment.

Alternative 2, LUCs, would not provide any reduction in toxicity, mobility or volume of contaminants through treatment, but would prevent exposure of the on-site worker to hazardous substances by the application of institutional and engineering controls.

Sub-Alternatives A-3a, A-3b, A-3c, and A-3d would not provide reduction in the toxicity, mobility, and volume of waste.

However, since a portion or all of the ash would be excavated and removed from the WADB there will be removal either of 16,820 or 61,332 m^3 (22,000 or 80,220 yd^3) of contaminated media from the excavation. Excavation of the ash will also reduce mobility of ash the plume. The ash would be interred safely in an approved solid waste disposal facility and there would be no future possibility of exposure of either the on-site worker or community to the contaminants in the ash.

Short-Term Effectiveness

Short term effectiveness is not applicable to Alternative 1 since there is no action.

Alternative 2 presents no risk to workers or the community since no waste is generated, transported, or disposed by implementing LUCs.

Sub-Alternatives A-3a, A-3b, A-3c, and A-3d have the potential to minimally expose remediation workers to hazardous substances during excavation, construction, hauling, and earth moving activities. The removal of contaminated soil and ash would be performed consistent with SRS safety and health procedures to ensure minimal impact to the remediation worker during implementation. There is no risk to the community from these activities since the work area is not located in proximity to any community and is well within the SRS boundary.

A major advantage is recognized by sub-Alternatives A-3a and A-3b because excavation and removal of ash and contaminated soil media is only partial and will not occur in a designated wetland. Sub-Alternatives A-3a and A-3b will not disturb, destroy, or negatively impact the sensitive ecosystem of the Dunbarton Bay and the buffer area. The buffer area is present to provide a barrier where construction activities will stop and be mitigated, thus preventing negative impact to and protecting the Dunbarton Bay from sedimentation, erosion, and destruction of flora and fauna.

Alternatively, sub-Alternatives A-3c and A-3d propose to excavate and remove the entire 61,332 m^3 (80,220 yd^3) of ash and contaminated soil media from WADB subunit. These sub-alternatives (while being the most effective for reducing receptor risk) are also the most destructive to the environment. In order to implement sub-Alternatives A-3c and A-3d, it will require clear cutting all the vegetation and mature trees, cutting and building temporary roads to provide access for heavy construction equipment, construction of temporary ash and contaminated soil staging areas, and excavation and removal of soil and ash in and around the Dunbarton Bay. The construction activities needed to implement A-3c and A-3d will virtually destroy and eliminate a portion of Dunbarton Bay as a natural resource. The construction activity and level of destruction to the Dunbarton Bay is an unavoidable impact of implementing these two sub-alternatives. Due to the volume and location of the ash and contaminated media, there is no other feasible method or technology to cost-effectively accomplish the excavation without causing extensive and possibly irreversible destruction of the Dunbarton Bay.

Implementation

No implementation is required under the No Action alternative.

Alternative 2, LUCs has been implemented successfully within SRS at other waste units. There are no administrative or technical impediments for implementing LUCs at SRS. The time to implement Alternative 2 is approximately 6 months.

Sub-Alternatives A-3a and A-3b can also be readily implemented using standard construction techniques for excavation and hauling the ash and contaminated soil media to an approved on-SRS or off-SRS ex situ containment facility.

A major disadvantage of sub-Alternatives A-3c and A-3d is they may not be readily implemented or there may be difficulty associated with the construction because of working in the wetlands. Working conditions in a designated wetlands will be more restrictive to mitigate damage from construction and more costly to restore (if possible) damage caused by the construction.

Another significant disadvantage for sub-Alternatives A-3c and A-3d is if heavy precipitation should occur prior to or during the construction period it may cause construction activities to be significantly delayed because Dunbarton Bay has the potential to accumulate precipitation. This condition would probably stop construction for an unknown period of time until conditions became suitable for earth-moving activities to restart.

Alternatively, permits for implementing sub-alternatives A-3c and A-3d may be more difficult to obtain. While work performed under these sub-Alternatives also use standard earth working and earth moving methods, the work will be performed in a designated wetland; thereby, increasing the length of time to obtain a permit.

Permitting for implementation of sub-alternative A-3a may be very difficult to obtain as well as very costly (costs estimated between $1.5 to $10 million for the engineering and construction work to obtain an approved solid waste disposal facility permit). Conversely, permitting for implementing sub-alternative A-3b should not be difficult to obtain. The ash/soil media may be excavated and hauled to a currently permitted solid waste disposal facility which meets all South Carolina regulations. It is not certain if

SRS could even expeditiously obtain the appropriate South Carolina solid waste permits, so there is high uncertainty if on-SRS ex situ disposal is feasible in a timely manner. The cost advantage of A-3a could easily be lost by the costs associated with obtaining the permits required to implement this alternative ($1.5 to $10 million for engineering, preparation and siting). Therefore, a tradeoff for a more certain disposition route for disposal of the ash/soil media is justified instead of a less certain disposition route which has an uncertain outcome and potentially higher costs. This same concern includes sub-alternative A-3c as well.

The time required to implement alternative A-2 is 6 months. The time to implement sub-alternatives A-3a and A-3b is 12 months and the time to implement sub-alternatives A-3c and A-3d is 18 months

Cost

The evaluation of an alternative must include capital, present-worth operational and maintenance costs. The cost estimates presented herein are based on the best available information regarding the anticipated scope of the alternatives. Changes in the cost of elements are likely to occur as a result of new information and data collected during the engineering design of the selected alternative. This is an order of magnitude engineering cost estimate expected to be within –30 to +50 percent of the actual project cost. The final cost of the project depends on actual labor and material cost, actual site conditions, productivity, competitive market conditions, final project scope, final project schedule, weather, diesel fuel cost, and other variables. The detailed cost estimates are provided in Appendix F.

The total estimated costs for all alternatives are summarized in the table below:

Remedial Alternative	Total Estimated Cost
A-1 No Action	$0
A-2 Land Use Controls	$1,824,099
A-3a Excavate 22,000 yd^3/on-SRS ex situ containment, LUCs	$8,275,378*
A-3b Excavate 22,000 yd^3/off-SRS ex situ containment, LUCs	$11,535,146
A-3c Excavate 80,220 yd^3/on-SRS ex situ containment, no LUCs	$13,055,204*
A-4d Excavate 80,220 yd^3/off-SRS ex situ containment, no LUCs	$21,428,462

*Does not include costs associated with On-SRS containment facility (i.e., preparation, engineering permitting, or receiving waste). Estimates range between $1.5 to $10 million additional in costs.

The least expensive alternative is A-1, No Action. A-1 cannot meet the threshold criteria since it is not protective of human health and it is not protective of the environment.

Alternative A-2 is the least expensive alternative and can meet the threshold criteria, but does not reduce residual risk, or A-2 is not permanent and leaves hazardous substances in place. Also A-2 provides no treatment or removal of hazardous substances. However, A-2 is effective in preventing human exposure to contaminants by the use of administrative and engineering controls for the least cost.

Sub alternatives A-3a and A-3b meet all the threshold criteria and reduce the volume of contaminated media by excavation and removal of 16,741 m^3 (591,187 ft^3 or 22,000 yd^3) to an in-situ containment facility and is permanent. A-3a can also achieve ARARs the best of any of the removal alternatives. A-3a and A-3b also reduce the residual risk in the excavated area to less than 1E-06 or background concentrations. A-3a is the least expensive of the excavation sub-alternatives and is one of the best alternatives to protect the environment by establishing a 30-m (100-ft) buffer around the Dunbarton Bay to prevent excavation activities from injuring the sensitive ecosystem of the bay. LUCs are combined with this sub-alternative to prevent human exposure to the ash and contaminated soil media that will remain in the Dunbarton Bay. A-3b provides the same level of advantages and disadvantages at a greater cost since ex situ containment will require payment of tipping fees and higher hauling costs. A-3a and A-3b are also the most implementable since work is not performed in a designated wetlands. In the final analysis, A-3b may be the more feasible sub-alternative since there is an assured disposition pathway for the ash/soil media which can attain the project schedule whereas

A-3a does not have an assured pathway for waste disposition. There is high uncertainty of a guaranteed disposal path for waste destined for on-SRS disposal for sub-alternative A-3a. This includes sub-alternative A-3c as well. Even though A-3a has the cost advantage, due to the uncertainty of the costs and time associated with obtaining the appropriate permits and engineering and construction of an approved solid waste disposal facility, this advantage could easily be lost. Therefore, there is a tradeoff of preference for A-3b which has a predictable and certain pathway for disposal of waste.

Sub-alternative A-3c meets all the threshold criteria, removes the total volume and mobility of contaminated media by excavation of 61,332 m^3 (80,220 yd^3) and disposal in an ex-situ containment facility. A-3c removes all ash and contaminated soil media to an on-SRS containment facility. It is the optimal excavation sub-alternative because all contaminated media from the WADB is excavated and permanently removed. LUCs are not required because all contaminated media is removed. However, A-3c is also least protective of the environment since, under this sub-alternative, the Carolina Bay would require clearing and grubbing, road construction, grading, vegetation removal, and excavation of contaminated media in the bay. This sub-alternative would cause the most detriment to the environment and cause the most destruction of the Dunbarton Bay of all sub-alternatives. There is a possibility of significant implementation problems caused by water accumulation in the wetlands and for obtaining permits for construction in the wetlands. A-3c is more expensive to implement than A-3a and A-3b because a larger volume of contaminated media is excavated and disposed. A-3d provides the same advantages and disadvantages as A-3c, but is more expensive to implement since ex situ containment will require payment of tipping fees and higher hauling costs.

4.2 Summary of Analysis

With the exception of the No Action Alternative, all the alternatives meet the threshold criteria and the balancing criteria and represent a range of remedial alternatives focused to the scope and subtleties of the problem. Alternative A-2 and sub-alternatives A-3a, A-3b, A-3c, A-3d are all protective of the IOU on-site worker and can meet the RAOs for the WADB, but all alternatives are not optimal for protection of the environment.

Alternative A-2 is the least expensive alternative to be protective of the IOU on-site worker, but leaves hazardous substances in place and residual risk remains greater than 1E-06 or SRS background concentrations.

A-3a and A-3b are the optimal sub-alternatives to achieve protection of the environment and the ARARs. These sub-alternatives are the least expensive of the excavation alternatives and also the optimal alternatives for protection of the environment by establishing a 30-m (100-ft) buffer around the Dunbarton Bay to prevent injury of the sensitive ecosystem of the bay. LUCs are combined with these sub-alternatives to prevent human exposure to the contaminated media that will remain in the Dunbarton Bay. A-3a is the least expensive of the two because excavated ash and soil are hauled to an on-SRS ex situ containment facility; however, such a facility currently does not exist due to changes in regulations pertaining to ash, A-3b may be the best tradeoff for its guaranteed path for waste disposal at a currently approved solid waste disposal facility. A-3a could potentially require $1.5 to $10 million for engineering, construction, and development of an approved solid waste disposal facility on-SRS.

A-3c and A-3d excavate and haul all ash and contaminated soil media to an ex situ containment facility and are the optimal excavation alternatives. All contaminated media from the WADB is excavated and permanently removed. The tradeoff is these sub-alternatives would be the most detrimental to the environment and cause more destruction of the Dunbarton Bay and also would be the most difficult to implement than any of the other sub-alternatives. A-3d is more expensive to implement than A-3c because contaminated media is excavated and hauled to an off-SRS ex-situ containment facility requiring payment of tipping fees.

The qualitative ranking is shown in Table 4-2.

Table 4-1. Comparison of the Alternatives to the Nine CERCLA Criteria

	A-1	A-2	A-3a	A-3b*	A-3c	A-3d*
Criterion	**No Action**	**Land Use Controls**	**Excavation On-SRS Containment and LUCs (22,000 yd^3)**	**Excavation Off-SRS Containment and LUCs (22,000 yd^3)**	**Excavation On-SRS Containment (80,220 yd^3)**	**Excavation Off-SRS Containment (80,220 yd^3)**
Overall Protection of Human Health and the Environment						
Human Health	Not protective of the IOU on-site worker because there are no controls or remediation	Minimally protective of the IOU on-site worker because of access controls	More protective of IOU on-site worker because a portion of contaminants are removed	More protective of IOU on-site worker because a portion of contaminants are removed	Optimally protective of the IOU on-site worker because all contaminants are removed	Optimally protective of the IOU on-site worker because all contaminants are removed
Environment	Not protective because contaminants remain in place	Protective of the environment because no eco/CM/PTSM RCOCs	Optimally protective of environment because Carolina Bay is protected	Optimally protective of environment because Carolina Bay is protected	Least protective and causes more destruction of the Carolina Bay than any of the other sub-alternatives	Least protective and causes more destruction of the Carolina Bay than any of the other sub-alternatives
Compliance with ARARs						
Chemical-Specific	No ARARs exist	No ARARs exist	If soils are found to be hazardous, SC *Hazardous Waste Management Regulation* (SC R61-79); *Listing of Hazardous Waste* (40 CFR-261)	If soils are found to be hazardous, SC Hazardous Waste Management Regulation (SC R61-79); Listing of Hazardous Waste (40 CFR-261)	If soils are found to be hazardous, SC Hazardous Waste Management Regulation (SC R61-79); Listing of Hazardous Waste (40 CFR-261)	If soils are found to be hazardous, SC Hazardous Waste Management Regulation (SC R61-79); Listing of Hazardous Waste (40 CFR-261)
Location-Specific	No ARARs exist	No ARARs exist	Various federal and South Carolina regulations are applicable for protection and mitigation of damage to wetlands	Various federal and South Carolina regulations are applicable for protection and mitigation of damage to wetlands	Various federal and South Carolina regulations are applicable for protection and mitigation of damage to wetlands	Various federal and South Carolina regulations are applicable for protection and mitigation of damage to wetlands
Action-Specific	No ARARs exist	No ARARs exist	Various federal and South Carolina regulations are applicable for management of stormwater and solid waste disposal	Various federal and South Carolina regulations are applicable for management of stormwater and solid waste disposal	Various federal and South Carolina regulations are applicable for management of stormwater and solid waste disposal	Various federal and South Carolina regulations are applicable for management of stormwater and solid waste disposal

Table 4-1. Comparative of the Alternatives to the Nine CERCLA Criteria *(Continued)*

	A-1	A-2	A-3a	A-3b*	A-3c	A-3d*
Criterion	**No Action**	**Land Use Controls**	**A-3a Excavation On-SRS Containment and LUCs (22,000 yd^3)**	**Excavation Off-SRS Containment and LUCs (22,000 yd^3)**	**Excavation On-SRS Containment (80,220 yd^3)**	**Excavation Off-SRS Containment (80,220 yd^3)**
Long-Term Effectiveness and Performance						
Magnitude of Residual Human Health Risk	Residual human health risk remains above $1x10^{-6}$ or SRS background concentrations	Residual human health risk remains above $1x10^{-6}$ or SRS background concentrations	Residual human health risk less than 1x10-6 or SRS background concentrations and not greater than $9.9x10^{-5}$ in Dunbarton Bay; 5 year remedy reviews required; 25 acres require LUCs	Residual human health risk less than $1x10^{-6}$ or SRS background concentrations and not greater than $9.9x10^{-5}$ in Dunbarton Bay: 5 year remedy reviews required; 25 acres require LUCs	Residual human health risk less than $1x10^{-6}$ or SRS background concentrations; no 5 year remedy reviews required, LUCs not required	Residual human health risk less than $1x10^{-6}$ or SRS background concentrations; no 5 year remedy reviews required, LUCs not required
Adequacy of Controls	Not adequately protective of human health receptors	Effective in preventing exposure to human receptors and breaking the exposure pathway. Leaves contaminants in place. LUCs required as long as contaminants are present	Controls are adequate because 22,000 yd^3 of contaminated media is removed from wetland and LUCS are required for Dunbarton Bay	Controls are adequate because 22,000 yd^3 of contaminated media is removed from wetland and LUCS are required for Dunbarton Bay	Controls will not be required because the entire volume of 80,220 yd^3 contaminated media is removed	Controls will not be required because the entire volume of 80,220 yd^3 contaminated media is removed
Permanence	Not permanent. Leaves contaminants ash/soil media in the wetlands	Not permanent. Leaves contaminants ash/soil media in the wetlands	Excavation of 22,000 yd^{3}of contaminated media will be permanent; contaminated media remains in Dunbarton Bay to prevent destruction of ecosystem:	Excavation of 22,000 yd^{3}of contaminated media will be permanent; contaminated media remains in Dunbarton Bay to prevent destruction of ecosystem	Excavation of 80,220 yd^{3}of contaminated media will be permanent	Excavation of 80,220 yd^{3}of contaminated media will be permanent
Treatment						
Treatment type	No active treatment	No active treatment	No active treatment	No active treatment	No active treatment	No active treatment
Degree of Expected Reduction in Toxicity, Mobility, or Volume	No reduction	No reduction	No reduction via treatment	No reduction via treatment	No reduction via treatment	No reduction via treatment

Table 4-1. Comparative of the Alternatives to the Nine CERCLA Criteria *(Continued)*

	A-1	A-2	A-3a	A-3b*	A-3c	A-3d*
Criterion	**No Action**	**Land Use Controls**	**Excavation On-SRS Containment and LUCs (22,000 yd^3)**	**Excavation Off-SRS Containment and LUCs (22,000 yd^3)**	**Excavation On-SRS Containment (80,220 yd^3)**	**Excavation Off-SRS Containment (80,220 yd^3)**
Short-Term Effectiveness and Performance						
Amount of Hazardous Material Destroyed or Treated	None	None	None	None	None	None
Risk to Remedial Worker	None	None	Minimal; Health and Safety Plan will be implemented to protect remedial workers	Minimal; Health and Safety Plan will be implemented to protect remedial workers	Minimal; Health and Safety Plan will be implemented to protect remedial workers	Minimal; Health and Safety Plan will be implemented to protect remedial workers
Risk to Community	None	None	None	None	None	None
Risk to Environment	None	None	Low; Dunbarton Bay is protected by a 100-foot buffer; no construction activity in bay	Low; Dunbarton Bay is protected by a 100-foot buffer; no construction activity in bay	High; likely destruction of Dunbarton Bay and ecosystem	High; likely destruction of Dunbarton Bay and ecosystem
Time to Implement and achieve RAO	Never	6 months	12 months	12 months	18 months	18 months
Implementability						
Availability of Materials, Equipment, Contractors	Not Applicable	Not Applicable	Readily Available	Readily Available	Readily Available	Readily Available
Ability to Construct and Operate the Technology	Not applicable	Not Applicable	Straight forward	Straight forward	May be difficult if precipitation accumulates in wetland	May be difficult if precipitation accumulates in wetland
Ability to Obtain Permits/Approvals from Other Agencies	Not Applicable	Not Applicable	Complicated due to permitting issues with H-Area; Will require lead time to procure required permits; permits required before remedial action can begin	Easy; no impediments	Difficult if wetlands are excavated; Will require lead time to procure required permits; permits required before remedial action can begin	Difficult if wetlands are excavated; Will require lead time to procure required permits; permits required before remedial action can begin

Table 4-1. Comparative of the Alternatives to the Nine CERCLA Criteria
(Continued/End)

	A-1	A-2	A-3a	A-3b*	A-3c	A-3d*
Criterion	**No Action**	**Land Use Controls**	**Excavation On-SRS Containment and LUCs (22,000 yd^3)**	**Excavation Off-SRS Containment and LUCs (22,000 yd^3)**	**Excavation On-SRS Containment (80,220 yd^3)**	**Excavation Off-SRS Containment (80,220 yd^3)**
Estimated Cost						
Total Capital Cost	$0	$115,362	$6,566,642	$9,826,409	$12,956,534	$21,329,792
Present Worth O&M Cost	$0	$1,708,737	$1,708,737	$1,708,737	$98,670	$98,670
Total Cost	$0	$1,824,099	$8,275,378*	$11,535,146	$13,055,204*	$21,428,462

*Does not include costs associated with On-SRS receiving facility (i.e., preparation, permitting or receiving waste). Estimates range between $1.5 to $10 Million additional costs.

Table 4-2. Comparative Analysis of Alternatives for the Wetland Area at Dunbarton Bay Subunit

Alternatives	Overall Protection of Human Health	Overall Protection of Environment	Achieves RAOs	Achieves ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-Term Effectiveness	Implementability	Cost	Overall Ranking
A-1 – No Action	No	No	No	NA	1	1	1	5	5	13
A-2 – Land Use Controls	Yes	Yes	Yes	NA	3	1	5	5	5	19
A-3a Excavation on-SRS Containment	Yes; better	Yes; optimal	Yes	5	3	1	5	2	2	18
A-3b Excavation off-SRS Containment	Yes; better	Yes; optimal	Yes	5	5	1	5	5	3	22
A-3c Excavation on-SRS Containment	Yes; optimal	Yes, but most destructive to environment	Yes	5	5	1	2	2	2	17
A-3d Excavation off-SRS Containment	Yes; optimal	Yes, but most destructive to environment	Yes	5	5	1	2	3	1	17

Scale
1=Minimum 5=Maximum

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APPENDIX A

Data

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Appendix A-1

Statistical Summary Table for the 0- to 1-Ft Ash (Soil/Sediment) Interval (Verified and Validated Data)

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Table A-1. Dunbarton Bay Statistical Summary Table for the 0 – 1 Ft Ash/Soil Interval

Analyte	Units	Samples	Non-Detects	Detects	J-Detects	Distribution	UCL Method	Mean	95% UCL of Mean	Max	Min	RME	Max Location	Qualifier of Max
Inorganics														
Aluminum	mg/kg	10	0	10	0	N	1	4363	5214	6970	2020	5214	PAB-120	---
Arsenic	mg/kg	10	0	10	2	N	1	14.8	21.4	33.6	1.82	21.4	PAB-120	---
Barium	mg/kg	10	0	10	0	N	1	68.2	93.4	144	10.0	93.4	PAB-183	---
Beryllium	mg/kg	10	0	10	2	N	1	1.08	1.46	2.08	0.114	1.46	PAB-120	---
Cadmium	mg/kg	10	8	2	2	X	4	0.116	0.224	0.224	ND	0.224	PAB-120	J
Calcium	mg/kg	10	0	10	0	N	1	976	1369	2090	115	1369	PAB-183	---
Chromium	mg/kg	10	0	10	0	N	1	8.15	10.67	15.4	3.40	10.67	PAB-301	---
Cobalt	mg/kg	10	0	10	1	N	1	3.38	4.94	7.60	0.43	4.94	PAB-120	---
Copper	mg/kg	10	0	10	0	N	1	20.7	30.8	55.8	1.49	30.8	PAB-120	---
Iron	mg/kg	10	0	10	0	N	1	6887	9432	14200	787	9432	PAB-120	---
Lead	mg/kg	10	0	10	0	N	1	8.48	10.64	13.6	3.62	10.64	PAB-120	---
Magnesium	mg/kg	10	0	10	0	N	1	201.4	267.9	360	72.3	267.9	PAB-153	---
Manganese	mg/kg	10	0	10	0	G	2	94.2	211	354	9.15	211	PAB-183	---
Mercury	mg/kg	10	0	10	2	N	1	0.038	0.0533	0.0773	0.00792	0.0533	PAB-120	---
Nickel	mg/kg	10	0	10	0	N	1	6.84	9.57	12.6	1.02	9.57	PAB-120	---
Potassium	mg/kg	10	0	10	0	N	1	318	431	584	53.7	431	PAB-183	---
Selenium	mg/kg	10	0	10	7	N	1	2.57	3.50	5.44	0.61	3.50	PAB-120	---
Silver	mg/kg	10	6	4	4	X	4	0.12	0.174	0.204	ND	0.174	PAB-183	J
Sodium	mg/kg	10	2	8	1	X	4	33.0	44.8	61.2	ND	44.8	PAB-153	---
Thallium	mg/kg	10	2	8	5	X	5	1.67	2.43	3.67	ND	2.43	PAB-183	---
Vanadium	mg/kg	10	0	10	0	N	1	17.4	20.9	25.8	6.39	20.9	PAB-120	---
Zinc	mg/kg	10	0	10	0	N	1	20.8	31.4	55.0	2.62	31.4	PAB-120	---
Radionuclides														
Actinium-228	pCi/g	10	0	10	1	N	1	2.21	2.42	2.50	0.389	2.42	PAB-182	---
Cesium-137	pCi/g	10	0	10	1	N	1	2.32	3.42	5.19	0.0513	3.42	PAB-120	---
Potassium-40	pCi/g	10	1	9	0	X	5	9.69	13.3	16.4	ND	13.3	PAB-153	---
Radium-226	pCi/g	10	0	10	0	X	3	1.74	2.82	2.38	0.347	2.38	PAB-183	---
Radium-228	pCi/g	10	0	10	1	N	1	1.70	2.11	2.50	0.389	2.11	PAB-182	---
Thorium-228	pCi/g	10	0	10	0	N	1	1.49	1.87	2.21	0.4	1.87	PAB-116	---
Thorium-230	pCi/g	10	0	10	3	N	1	1.68	2.19	2.71	0.243	2.19	PAB-116	---

Table A-1. Dunbarton Bay Statistical Summary Table for the 0 – 1 Ft Ash/Soil Interval *(Continued/End)*

Analyte	Units	Samples	Non-Detects	Detects	J-Detects	Distribution	UCL Method	Mean	95% UCL of Mean	Max	Min	RME	Max Location	Qualifier of Max
Radionuclides *(Cont'd)*														
Thorium-232	pCi/g	10	0	10	0	N	1	1.51	1.87	2.29	0.454	1.87	PAB-153	---
Uranium-233/234	pCi/g	10	0	10	1	X	3	1.65	2.69	2.40	0.205	2.40	PAB-301	---
Uranium-235	pCi/g	10	4	6	5	X	4	0.098	0.145	0.176	ND	0.145	PAB-116	J
Uranium-238	pCi/g	10	0	10	0	N	1	1.62	2.07	2.51	0.294	2.07	PAB-301	---

Distribution Code:
N Normal Distribution
ND Non-Detect
G Gamma Distribution
X Non-Parametric

UCL Method Code: (as determined by ProUCL)
1. Student's-t UCL
2. 95% Approximate Gamma UCL
3. 95% Chebyshev (Mean, Sd) UCL
4. 95% KM (Percentile Bootstrap) UCL
5. 95% KM (t) UCL

Appendix A-2:

Dunbarton Bay Surface Water Sample Results
(Verified and Validated Data)

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Table A-2. Dunbarton Bay Surface Water Sample Results

STATION	ANALYTE	METHOD	MDL	PQL	STORET	LABQUAL	EPACODE	REPORTED RESULT	UNITS	MATRIX
PAB-428	Aluminum	EPA6010C	68	200				500	µg/L	SFWATER
PAB-429	Aluminum	EPA6010C	68	200				1930	µg/L	SFWATER
PAB-428	Antimony	EPA6010C	3	10		U	U	10	µg/L	SFWATER
PAB-429	Antimony	EPA6010C	3	10	21	J	J	4.54	µg/L	SFWATER
PAB-428	Arsenic	EPA6010C	5	30		U	U	30	µg/L	SFWATER
PAB-429	Arsenic	EPA6010C	5	30				46.5	µg/L	SFWATER
PAB-428	Barium	EPA6010C	1	5				49	µg/L	SFWATER
PAB-429	Barium	EPA6010C	1	5				93.5	µg/L	SFWATER
PAB-428	Calcium	EPA6010C	50	200				3430	µg/L	SFWATER
PAB-429	Calcium	EPA6010C	50	200				17300	µg/L	SFWATER
PAB-428	Chromium	EPA6010C	1	5	21	J	J	1.23	µg/L	SFWATER
PAB-429	Chromium	EPA6010C	1	5				7.65	µg/L	SFWATER
PAB-428	Cobalt	EPA6010C	1	5	21	J	J	1.81	µg/L	SFWATER
PAB-429	Cobalt	EPA6010C	1	5				5.89	µg/L	SFWATER
PAB-428	Copper	EPA6010C	3	10		U	U	10	µg/L	SFWATER
PAB-429	Copper	EPA6010C	3	10	21	J	J	5.07	µg/L	SFWATER
PAB-428	Iron	EPA6010C	30	100				858	µg/L	SFWATER
PAB-429	Iron	EPA6010C	30	100				9550	µg/L	SFWATER
PAB-428	Magnesium	EPA6010C	85	300				902	µg/L	SFWATER
PAB-429	Magnesium	EPA6010C	85	300				2940	µg/L	SFWATER
PAB-428	Manganese	EPA6010C	2	10				230	µg/L	SFWATER
PAB-429	Manganese	EPA6010C	2	10				277	µg/L	SFWATER
PAB-428	Nickel	EPA6010C	1.5	5		U	U	5	µg/L	SFWATER
PAB-429	Nickel	EPA6010C	1.5	5				7.27	µg/L	SFWATER
PAB-428	Potassium	EPA6010C	50	150				262	µg/L	SFWATER
PAB-429	Potassium	EPA6010C	50	150				5920	µg/L	SFWATER
PAB-428	Sodium	EPA6010C	100	300				1150	µg/L	SFWATER
PAB-429	Sodium	EPA6010C	100	300				7480	µg/L	SFWATER
PAB-428	Vanadium	EPA6010C	1	5	21	J	J	2.96	µg/L	SFWATER
PAB-429	Vanadium	EPA6010C	1	5				25	µg/L	SFWATER
PAB-428	Zinc	EPA6010C	3.3	10				22.9	µg/L	SFWATER
PAB-429	Zinc	EPA6010C	3.3	10				33.1	µg/L	SFWATER
PAB-428	Nonvolatile Beta	RADA-001	3.09	6.85		U	U	1.97	pCi/L	SFWATER
PAB-429	Nonvolatile Beta	RADA-001	3.08	8.18				9.6	pCi/L	SFWATER
PAB-428	Radium-226	RADA-008	0.578	1.4	21	J	J	0.602	pCi/L	SFWATER
PAB-429	Radium-226	RADA-008	0.445	1.11	21	J	J	0.531	pCi/L	SFWATER

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Appendix A-3

Dunbarton Bay Groundwater Sample Results
(Verified and Validated Data)

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Table A-3. Summary Dunbarton Bay Groundwater Sampling Result

Analyte Name	Total Samples	# Detects	Units	Mean DL	Mean Detection	Minimum Detection	Maximum Detection
Arsenic	52	3	µg/L	2.54E+01	1.53E+00	1.30E+00	1.90E+00
Barium	52	52	µg/L	8.92E+00	3.55E+01	3.84E+00	1.73E+02
Beryllium	52	15	µg/L	6.92E-01	1.09E+00	1.03E-01	1.06E+01
Cadmium	32	7	µg/L	5.00E-01	1.56E-01	1.30E-01	2.00E-01
Chromium	32	3	µg/L	1.00E+01	4.20E+00	3.50E+00	5.40E+00
Cobalt	52	31	µg/L	3.46E+00	9.68E-01	2.70E-01	4.30E+00
Copper	52	36	µg/L	2.54E+00	1.08E+00	5.02E-01	3.40E+00
Gross Alpha	52	25	pCi/L	3.96E+00	2.87E+00	6.20E-01	1.82E+01
Iron	52	37	µg/L	6.92E+01	8.03E+02	1.09E+01	5.79E+03
Lead	52	36	µg/L	3.77E+00	1.05E+00	2.00E-01	6.00E+00
Manganese	52	48	µg/L	5.08E+00	1.58E+01	3.00E-01	7.16E+01
Mercury	10	0	µg/L	2.00E-01	ND	ND	ND
Nonvolatile Beta	52	21	pCi/L	5.37E+00	2.89E+00	8.40E-01	1.80E+01
Selenium	52	0	µg/L	8.85E+00	ND	ND	ND
Silver	32	6	µg/L	2.00E+00	4.12E-01	1.30E-01	1.40E+00
Tetrachloroethylene (PCE)	10	0	µg/L	5.00E-01	ND	ND	ND
Thallium	48	18	µg/L	1.58E+00	1.29E+00	1.57E-01	2.10E+00
Trichloroethylene (TCE)	10	0	µg/L	5.00E-01	ND	ND	ND
Tritium	10	7	pCi/L	5.41E-01	8.07E-01	1.49E-01	2.01E+00
Zinc	52	19	µg/L	1.96E+01	9.08E+00	3.23E+00	1.69E+01

DL = detection limit
ND = nondetect

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Appendix A-4

SREL 0- to 1-Ft Ash (Soil/Sediment) Interval Collected in 2011

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Table A-4. SREL 0- to 1-Ft Ash (Soil/Sediment) Interval Collected in 2011

DUN	Site	Depth Interval				Be	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se
		cm	pH_w	pH_{KCl}*	Clay**	mg/kg[#]											
009	1	0-30	4.85	4.17	2.6	5.28	18,461	57.6	28.3	112.8	20,025	6.93	29.6	102.1	78.5	40.9	7.84
010	2	0-30	5.43	4.60	3.1	0.05	3,312	3.0	2.3	44.0	1,665	0.49	1.1	0.9	2.0	0.6	0.33
011	3	5-35	4.81	4.13	2.1	2.83	9,100	28.7	13.2	37.1	7,288	4.75	13.4	29.2	30.4	24.0	4.80
012	4	3.75-33.75	5.22	4.49	1.4	1.68	7,853	17.2	7.8	53.1	12,102	3.69	8.8	18.6	19.7	13.7	2.77
013	5	0-30	4.92	4.19	2.5	3.46	11,694	39.4	19.0	133.5	10,552	6.37	21.8	73.3	52.4	31.5	8.39
014	6	5-35	5.31	4.51	2.1	2.64	11,691	27.4	9.8	43.7	10,781	5.40	11.6	22.6	27.4	9.9	3.77
015	7	5-35	4.58	4.24	7.8	0.08	4,276	2.3	2.2	1.9	325	0.16	<MDL	0.7	<MDL	0.3	<MDL
016	8	0-30	5.02	4.40	6.9	0.10	6,704	7.6	4.1	111.0	3,894	0.82	2.0	2.4	4.4	1.1	0.28
017	9 (1)	2.5-32.5	4.67	4.11	3.9	1.11	7,596	11.1	6.2	25.6	9,026	2.17	4.8	12.9	19.5	26.8	1.69
017	9 (2)	2.5-32.5	4.74	4.12	3.3	3.55	10,516	39.5	20.5	66.5	10,682	5.72	20.0	50.0	53.7	23.1	4.81
018	10	0-30	5.30	4.85	3	2.16	6,119	18.7	10.1	113.8	4,563	4.55	12.1	25.3	27.9	11.9	3.75
	Dunbarton Bay 100 Control Sites																
019	1	0-30	4.74	4.32	8.1	1.07	26,073	24.7	16.2	48.4	2,970	0.99	12.3	36.4	27.6	1.7	2.71
020	2	0-30	4.33	4.10	8.3	0.90	20,882	21.9	12.5	29.0	1,810	0.91	8.4	27.1	17.4	1.1	1.14
		MDL											0.89		1.20	0.29	0.2

DUN	Site	Depth Interval	Ag	Cd	Ba	Tl	Hg[##]	Pb
			mg/kg#					
009	1	0-30	<MDL	0.245	294.54	1.38	0.170	40.4
010	2	0-30	0.65	0.036	17.20	0.04	0.005	8.4
011	3	5-35	1.09781	0.167	171	1.03	0.075	15.5
012	4	3.75-33.75	<MDL	0.051	95.3	0.33	0.033	8.9
013	5	0-30	<MDL	0.249	163	1.30	0.116	28.8
014	6	5-35	<MDL	0.087	150	0.57	0.045	9.5
015	7	5-35	<MDL	<MDL	3.64	0.02	0.010	7.5
016	8	0-30	2.42	<MDL	20.2	0.06	0.009	8.4
017	9 (1)	2.5-32.5	<MDL	0.086	64.0	0.36	0.028	13.6
017	9 (2)	2.5-32.5	0.26417	0.187	170	1.43	0.062	29.9
018	10	0-30	<MDL	0.173	116	0.73	0.059	18.1
	Dunbarton Bay 100 Control Sites							
019	1	0-30	<MDL	0.230	139	0.13	0.020	17.8
020	2	0-30	<MDL	0.236	145	0.07	0.027	17.5
		MDL	0.22	0.018				

*pH in 1 M KCl
**Miller and Miller (1987) micro-pipette method
[#]Metals extracted by EPA Method 3051A.
[##]Hg analyzed by EPA method 7473

Depth Interval – When present, the organic detritus layer was removed and only the mineral soil was sampled for testing.
MDL – Method Detection Limit

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Appendix A-5

DUR for Dunbarton Bay

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United States Department of Energy

Savannah River Site

Wetland Area at Dunbarton Bay in Support of Steel Creek Integrated Operable Unit Data Usability Report (DUR)

SRNS-RP-2012-00571

Revision 0

August 2012

Prepared by:
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Prepared for
U.S. Department of Energy
and
Savannah River Nuclear Solutions, LLC
Aiken, South Carolina

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1.0 PROJECT SUMMARY

This report presents analytical data verification, validation and usability results for the sampling at the Wetland Area at Dunbarton Bay in support of Steel Creek Integrator Operable Unit, in accordance with document SGCP-SAP-2010-00007. The project generated 80 regular field samples, 6 field duplicate samples and 2 rinsate blanks. No trip blanks were required nor collected. The planned samples, along with the requested analytical analyses, are listed in Table 1.

Table 1. Sample Identification (ID) Summary

Station ID	Sample ID	Sample Type	Sample Date	Sample Time	Matrix	Interval	Analysis Requested
DUN004	DUN-IOU-00013	REG	-	-	Sfwater	-	Unused COC
DUN004	DUN-IOU-00053	REG	-	-	Sfwater	-	Unused COC
DUN001	DUN-IOU-00027	REG	-	-	Sfwater	-	Unused COC
DUN001	DUN-IOU-00063	REG	-	-	Sfwater	-	Unused COC
DUN002	DUN-IOU-00028	REG	-	-	Sfwater	-	Unused COC
DUN002	DUN-IOU-00064	REG	-	-	Sfwater	-	Unused COC
DUN003	DUN-IOU-00029	REG	-	-	Sfwater	-	Unused COC
DUN003	DUN-IOU-00065	REG	-	-	Sfwater	-	Unused COC
DUN005	DUN-IOU-00030	REG	-	-	Sfwater	-	Unused COC
DUN005	DUN-IOU-00066	REG	-	-	Sfwater	-	Unused COC
DUN006	DUN-IOU-00031	REG	-	-	Sfwater	-	Unused COC
DUN006	DUN-IOU-00067	REG	-	-	Sfwater	-	Unused COC
DUN007	DUN-IOU-00032	REG	-	-	Sfwater	-	Unused COC
DUN007	DUN-IOU-00068	REG	-	-	Sfwater	-	Unused COC
DUN008	DUN-IOU-00033	REG	-	-	Sfwater	-	Unused COC
DUN008	DUN-IOU-00069	REG	-	-	Sfwater	-	Unused COC
PAB-116	PAOU10DCB0012	REG	6/08/10	1054	Ash	0-1 ft.	2,3,9,10,11,12,13
PAB-117	PAOU10DCB0011	REG	6/08/10	1041	Soil	0-1 ft.	2,3,9,10,11,12,13
PAB-119	PAOU10DCB0013	REG	6/08/10	1142	Soil	0-1 ft.	2,3,9,10,11,12,13
PAB-120	PAOU10DCB0014	REG	6/08/10	1153	Ash	0-1 ft.	2,3,9,10,11,12,13
PAB-153	PAOU10DCB0015	REG	6/08/10	1308	Ash	0-1 ft.	2,3,9,10,11,12,13
PAB-182	PAOU10DCB0017	REG	6/08/10	1353	Ash	0-1 ft.	2,3,9,10,11,12,13
PAB-183	PAOU10DCB0016	REG	6/08/10	1341	Ash	0-1 ft.	2,3,9,10,11,12,13
PAB-301	PAOU10DCB0020	REG	6/08/10	1518	Ash	0-1 ft.	2,3,9,10,11,12,13
PAB-302	PAOU10DCB0019	REG	6/08/10	1507	Ash	0-1 ft.	2,3,9,10,11,12,13
PAB-304	PAOU10DCB0018	REG	6/08/10	1444	Soil	0-1 ft.	2,3,9,10,11,12,13
PAB-428	PAOU10DCB0021	REG	6/29/10	1255	Sfwater	-	1,2,3,12,13
PAB-429	PAOU10DCB0022	REG	6/29/10	1410	Sfwater	-	1,2,3,12,13
PAS001C	DUN-IOU-00021	REG	6/16/11	1130	Grwater	96-106 ft.	1,2,3,4,5,6,7,8,14
PAS001C	DUN-IOU-00044	REG	9/12/11	1020	Grwater	-	1,2

Table 1. Sample Identification (ID) Summary *(Continued)*

Station ID	Sample ID	Sample Type	Sample Date	Sample Time	Matrix	Interval	Analysis Requested
PAS001C	DUN-IOU-00058	REG	11/03/11	1040	Grwater	-	1,2
PAS001C	DUN-IOU-00077	REG	2/01/12	0839	Grwater	-	1,2
PAS001D	DUN-IOU-00022	FD	6/16/11	0955	Grwater	60-70 ft.	1,2
PAS001D	DUN-IOU-00023	REG	6/16/11	0955	Grwater	60-70 ft.	1,2,3,4,5,6,7,8,14
PAS001D	DUN-IOU-00045	FD	9/12/11	0834	Grwater	-	1,2
PAS001D	DUN-IOU-00046	REG	9/12/11	0834	Grwater	-	1,2
PAS001D	DUN-IOU-00059	FD	11/03/11	1236	Grwater	-	1,2
PAS001D	DUN-IOU-00060	REG	11/03/11	1236	Grwater	-	1,2
PAS001D	DUN-IOU-00078	REG	2/01/12	0927	Grwater	-	1,2
PAS002D	DUN-IOU-00025	REG	6/16/11	1415	Grwater	47-57 ft.	1,2,3,4,5,6,7,8,14
PAS002D	DUN-IOU-00047	FD	9/07/11	1259	Grwater	-	1,2
PAS002D	DUN-IOU-00048	REG	9/07/11	1259	Grwater	-	1,2
PAS002D	DUN-IOU-00061	REG	11/07/11	0924	Grwater	-	1,2
PAS002D	DUN-IOU-00079	REG	2/01/12	1330	Grwater	-	1,2
PAS003D	DUN-IOU-00024	FD	6/27/11	1128	Grwater	-	1,2,3,4,5,6,7,8,14
PAS003D	DUN-IOU-00026	REG	6/27/11	1128	Grwater	-	1,2
PAS003D	DUN-IOU-00049	REG	9/07/11	1451	Grwater	-	1,2
PAS003D	DUN-IOU-00062	REG	11/03/11	1454	Grwater	-	1,2
PAS003D	DUN-IOU-00080	REG	2/01/12	1422	Grwater	-	1,2
PGW-05A	DUN-IOU-00014	REG	7/11/11	0800	Grwater	-	1,2
PGW-05A	DUN-IOU-00037	REG	9/06/11	1341	Grwater	-	1,2
PGW-05B	DUN-IOU-00015	REG	7/11/11	0900	Grwater	-	1,2
PGW-05B	DUN-IOU-00038	REG	9/06/11	1443	Grwater	-	1,2
PGW-05C	DUN-IOU-00016	REG	7/11/11	1000	Grwater	-	1,2
PGW-05C	DUN-IOU-00039	REG	9/06/11	1518	Grwater	-	1,2
PGW-10B	DUN-IOU-00007	REG	4/19/11	1400	Grwater	-	1,2,3,4,5,6,7,8,14
PGW-10B	DUN-IOU-00017	REG	6/28/11	0930	Grwater	-	1,2
PGW-10B	DUN-IOU-00040	REG	9/02/11	1308	Grwater	-	1,2
PGW-10B	DUN-IOU-00054	REG	11/07/11	1048	Grwater	-	1,2
PGW-10B	DUN-IOU-00072	REG	2/01/12	1315	Grwater	-	1,2
PGW-10C	DUN-IOU-00008	REG	4/19/11	1408	Grwater	-	1,2,3,4,5,6,7,8,14
PGW-10C	DUN-IOU-00018	REG	6/27/11	1400	Grwater	-	1,2
PGW-10C	DUN-IOU-00041	REG	9/02/11	1400	Grwater	-	1,2
PGW-10C	DUN-IOU-00055	REG	11/07/11	1327	Grwater	-	1,2
PGW-10C	DUN-IOU-00073	FD	2/01/12	1431	Grwater	-	1,2
PGW-10C	DUN-IOU-00074	REG	2/01/12	1431	Grwater	-	1,2
PGW-10CU	DUN-IOU-00010	REG	4/18/11	1000	Grwater	-	1,2,3,4,5,6,7,8,14
PGW-10CU	DUN-IOU-00020	REG	6/18/11	0800	Grwater	-	1,2
PGW-10CU	DUN-IOU-00043	REG	9/07/11	1649	Grwater	-	1,2
PGW-10CU	DUN-IOU-00057	REG	11/02/11	1420	Grwater	-	1,2

Table 1. Sample Identification (ID) Summary *(Continued/End)*

Station ID	Sample ID	Sample Type	Sample Date	Sample Time	Matrix	Interval	Analysis Requested
PGW-10CU	DUN-IOU-00076	REG	2/01/12	1040	Grwater	-	1,2
PGW-10DL	DUN-IOU-00009	REG	4/18/11	1430	Grwater	-	1,2,3,4,5,6,7,8,14
PGW-10DL	DUN-IOU-00019	REG	6/18/11	0830	Grwater	-	1,2
PGW-10DL	DUN-IOU-00042	REG	9/07/11	1542	Grwater	-	1,2
PGW-10DL	DUN-IOU-00056	REG	11/02/11	1306	Grwater	-	1,2
PGW-10DL	DUN-IOU-00075	REG	2/01/12	1015	Grwater	-	1,2
RINSATE BLANK	DUN-IOU-00036	RB	-	-	Water	-	Unused COC
RINSATE BLANK	DUN-IOU-00052	RB	-	-	Water	-	Unused COC
RGW 7C	DUN-IOU-00011	REG	4/19/11	0930	Grwater	-	1,2,3,4,5,6,7,8,14
RGW 7C	DUN-IOU-00034	REG	6/28/11	1030	Grwater	-	1,2
RGW 7C	DUN-IOU-00050	REG	9/02/11	0940	Grwater	-	1,2
RGW 7C	DUN-IOU-00070	REG	11/08/11	0856	Grwater	-	1,2
RGW 7C	DUN-IOU-00081	REG	2/01/12	0847	Grwater	-	1,2
RGW 7D	DUN-IOU-00012	REG	4/19/11	1030	Grwater	-	1,2,3,4,5,6,7,8,14
RGW 7D	DUN-IOU-00035	REG	6/28/11	1400	Grwater	-	1,2
RGW 7D	DUN-IOU-00051	REG	9/02/11	1038	Grwater	-	1,2
RGW 7D	DUN-IOU-00071	REG	11/07/11	1430	Grwater	-	1,2
RGW 7D	DUN-IOU-00082	REG	2/01/12	1030	Grwater	-	1,2

Analyses Requested:

1. Gross Alpha/NVB
2. **Metals**
3. **Hg**
4. TCL Volatiles
5. Chloride
6. Sulfate
7. Total Phosphates
8. Total Suspended Solids
9. **Gamma Spec**
10. **Thorium series**
11. **Uranium series**
12. **Ra-226**
13. **Ra-228**
14. Tritium

Emboldened analytes were required by the SAP for the Wetland Area at Dunbarton Bay and the remaining analytes were required by the onsite Waste Acceptance Criteria .

A total of 1,336 analytical records were produced consisting of 1,246 regular records and 90 Field Quality Control (QC) records. Included in the 1246 regular records are 10 non-analyte specific records (TSS) which cannot be validated. See Table 2.

Table 2. Total Number of Records

Number of Records	Chemical	Radiochemical	Totals
Analytical	1,014	232	1,246
Field QC	78	12	90
Totals	1,092	244	1,336

The validation and verification processes are conducted to provide the data user with an indication of the quality and usability of analytical data. These processes involve examination of the electronic data files, the field data, and laboratory records. Computer programs are used to verify that samples were properly preserved were analyzed within the required holding time, that QC results were within specified acceptable ranges, and that the appropriate detection limits were employed by the laboratories. Additionally, manual reviews of field data and laboratory documentation records are conducted to ensure the quality of these items.

The data were validated to determine if the records conform to the technical criteria associated with definitive data per ER-SOP-033 guidance. Table 3 provides a brief validation summary for the project.

Table 3. Environmental Record Review Qualifier Summary

	Detects		Non-detects		Rejected	
Method Code	**# NULL Qualifiers**	**# J Qualifiers**	**# U Qualifiers**	**# UJ Qualifiers**	**# R Qualifiers**	**Total**
EPA160.2	8	0	2	0	0	10
EPA300.0	18	2	0	0	0	20
EPA365.2	4	5	1	0	0	10
EPA6010C	191	29	44	0	0	264
EPA6020A	144	204	392	2	4	746
EPA7470A	0	0	12	0	0	12
EPA7471B	8	2	0	0	0	10
EPA8260B	0	0	20	0	0	20
EPA900.0MOD	7	40	25	0	0	72
EPA906.0MOD	3	4	3	0	0	10
L3.21-10008	0	4	40	0	0	44
RADA-001	1	0	3	0	0	4
RADA-008	0	2	0	0	0	2
RADA-009	0	0	2	0	0	2
RADA-011	20	6	4	0	0	30
RADA-013	46	3	1	0	0	50
RADA-038	27	3	0	0	0	30
Total	**477**	**304**	**549**	**2**	**4**	**1,336**
% of Total	**36**	**23**	**41**	**0**	**0**	**100%**

2.0 ASSESSMENT OF PRECISION, ACCURACY, REPRESENTATIVENESS, COMPARABILITY, and COMPLETENESS DATA QUALITY INDICATORS (DQIs) AND MEASUREMENT PERFORMANCE CRITERIA (MPCs)

This section discusses the analytical data in terms of the following indicators of data quality: precision, accuracy, representativeness, comparability, and completeness. Precision is determined from the field and laboratory duplicate analyses and indicates the consistency of field and laboratory techniques. Accuracy is determined from the laboratory control samples (LCS) and indicates the ability of the laboratory to generate correct results. Representativeness measures how well the data represents the sample population. Comparability expresses the confidence with which data from different laboratories are considered to be equivalent. Representative completeness measures the amount of data resulting from the data collection activity.

2.1 Precision

Precision is the degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. Field duplicates measure the repeatability of the sampling and analytical techniques, and laboratory duplicates measure the ability of the laboratory to reproduce a result. Low precision can be caused by poor instrument performance, poor operator technique, inconsistent application of method protocols, laboratory environment, time between analyses, or by a difficult, heterogeneous sample matrix. Precision is especially important when the action limit approaches the quantification limit. A total of 9 % of the samples were collected in duplicate for this project in accordance with the SAP. The laboratory performs duplicate analyses on at least 5% of the samples received.

Precision is expressed in terms of the relative percent differences (RPD) as follows:

$$RPD = \frac{|x - y|}{\left(\frac{x + y}{2}\right)} \times 100$$

where x is the original sample result and y is the duplicate sample result. When one result of a duplicate pair is below the MDL, the ssEQL is used for that result in the calculation. When both results are below the MDL, the RPD is not calculated.

The RPD should be less than 20% for water samples and less than 35% for solid samples when results are greater than the ssEQL. In the case where results are between the ssEQL and the MDL, the RPD should be less than 100% for water samples and less than 200% for soil samples. In the event analytical precision goals are not met, a determination of the usability of that information is made through the environmental data assessment process.

No records were rejected due to precision issues. Details for this project can be found in subsections 3.6, *Laboratory Duplicate RPD*; and 3.7, *Field Duplicate RPD*.

2.2 Accuracy

Accuracy is defined as the closeness of agreement between an observed value and an accepted reference value. Accuracy is especially important when the concentration of concern approaches the detection limit and/or the action limit. When the concentration is underestimated near the detection limit, the analyte may be present but reported as not detected. When the concentration is underestimated near the action limit, the analyte may be at a concentration that would require remediation, but the remediation would not be performed. When the concentration is overestimated near the detection limit, the analyte may not be present but reported as detected. When the concentration is overestimated near the action limit, the analyte may not be at a concentration that would require remediation, but the remediation would be performed. The sample types used to evaluate accuracy are performance evaluation studies and laboratory control samples (LCSs).

LCSs monitor the performance of all steps in the analytical process, including sample preparation, and are used to identify problems with the analytical procedure. LCSs are deionized water that is spiked with the target analyte, digested, and analyzed with the regular samples. The LCS spiking solution is obtained from a third-party supplier, or is prepared in the laboratory using chemicals from a different source than the calibration standards.

The LCS percent recovery is calculated as follows:

$$\%\,\text{Recovery} = \frac{\text{Blank spike concentration}}{\text{Spike concentration}} \times 100$$

One hundred percent recovery is equivalent to 100% accuracy. Values less than 100% or greater than 100% may indicate a sample matrix effect and a false reading. A periodic program of sample spiking is required (e.g., one MS and one MS duplicate per 20 samples). In the event that analytical accuracy goals are not met, a determination is made through the environmental data assessment process relative to the usability of that information.

Four records for thallium were rejected due to matrix interference. Details for this project can be found in subsections 3.4, *Trip Blanks*; 3.5, *Method Blanks*; 3.8, *Matrix Spike Recovery*; 3.9, *LCS Recovery*; and 3.10, *Surrogate/Tracer Recovery*.

2.3 Representativeness

The representativeness of samples collected is controlled by adhering to the detailed descriptions of sampling procedures. Representativeness expresses the relative degree to which the data depict the characteristics of a population, parameter, sampling point, process condition, or environmental condition. The objective of this study is to accurately represent the concentrations of target analytes or compounds. Representative samples for this investigation will be required by implementing approved sampling and analytical procedures that will generate data representative of the sampling point location and will be maintained. Analytical methods are selected that will most accurately represent the true concentration of the parameter of interest. The accumulation of QC procedures and information (i.e., RPD values, blank QC concentrations, MS percent recoveries, etc.) employed for a given analysis combine to exhibit the representativeness of the data generated.

The goal for representative sample data will therefore be met by properly documenting field and analytical protocols. In the event these procedures and methods are not able to be implemented, the appropriate corrective action documentation should encompass the impact on the representativeness of the information. When review of the data and documentation determines the data to be non-representative, the information is qualified in its use or is not used by the project.

The samples were collected and analyzed per established procedures.

2.4 Comparability

Comparability is the degree to which different methods, data sets, and decisions agree or can be represented as similar. The comparability of the data from the laboratories is based on the results of the split samples and on confirmation that the laboratories used the same standardized procedures for sample analysis, the same reporting unit, and obtained similar quantitation limits. Comparability of the data produced for this investigation may be obtained by implementing the identified protocols for sampling and analysis of samples. Implementation of traceable reference materials such as laboratory standards, expression of results in standard concentration units, and successful participation by the laboratories in external performance evaluation programs will enable the information produced through this investigation to be compared with future data sets, if required. For this project, split samples were not collected and not sent to a designated QC laboratory.

2.5 Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared with the amount that was expected to be obtained under correct, normal circumstances. The Quality Assurance (QA) completeness objective for RFI/RI projects is to obtain valid field and laboratory analytical results for at least 95% of the samples collected during the project. This implies that completeness of sample collection (i.e., the number of samples collected compared to the number of samples planned) must be virtually 100% to allow for some loss of data during the laboratory analytical process. Accountability of samples collected, from field to final disposal, must be 100%.

Completeness is a measure of the amount of data obtained from a measurement process that achieves the project goals as compared to the amount of data planned to be obtained by the project. Completeness is affected by unexpected conditions during the data collection process that reduce the usable data achieved relative to the data planned. For this project, 16 planned surface water samples were not collected due to dry conditions, and the 2 planned rinsate samples were therefore not needed.

When review of the data and documentation determines the data to be incomplete, the impact relative to the project objective will be assessed and documented.

The following are measures of completeness:

Sample Collection:

$$\text{Completeness} = \frac{\text{Number of Sample Points Sampled}}{\text{Number of Sample Points Planned}} \times 100$$

Field Measurement:

$$\text{Completeness} = \frac{\text{Number of Valid Measurements Made}}{\text{Number of Measurements Planned}} \times 100$$

Laboratory Analysis:

$$\text{Completeness} = \frac{\text{Number of Valid Data Points}}{\text{Number of Data Points Planned}} \times 100$$

The completeness numbers for this project are listed below:

- Sample Collection Completeness 80%
- Field Measurement Completeness 100%
- Laboratory Analysis Completeness 99.7%

3.0 VALIDATION FINDINGS

3.1 Holding Times

Holding times for the reported analyses were within the recommended limits, as shown in Table 4. No qualification was required.

Table 4. Holding Time (HT) Review Qualifier Summary

Method Code	Total # of Records	# of Records Qualified for HT	Associated Samples Qualified
EPA160.2	10	0	
EPA300.0	20	0	
EPA365.2	10	0	
EPA6010C	264	0	
EPA6020A	746	0	
EPA7470A	12	0	
EPA7471B	10	0	
EPA8260B	20	0	
EPA900.0MOD	20	0	
EPA906.0MOD	72	0	
L3.21-10008	44	0	

Table 4. Holding Time (HT) Review Qualifier Summary *(Continued/End)*

Method Code	Total # of Records	# of Records Qualified for HT	Associated Samples Qualified
RADA-001	4	0	
RADA-008	2	0	
RADA-009	2	0	
RADA-011	30	0	
RADA-013	49	0	
RADA-038	30	0	

3.2 Preservation

All chemical and physical preservation for the reported analyses were properly applied. No qualification was required.

Table 5. Preservation Review Qualifier Summary

Method Code	Total # of Records	# of Records Qualified for Preservation	Associated Samples Qualified
EPA160.2	10	0	
EPA300.0	20	0	
EPA365.2	10	0	
EPA6010C	264	0	
EPA6020A	746	0	
EPA7470A	12	0	
EPA7471B	10	0	
EPA8260B	20	0	
EPA900.0MOD	20	0	
EPA906.0MOD	72	0	
L3.21-10008	44	0	
RADA-001	4	0	
RADA-008	2	0	
RADA-009	2	0	
RADA-011	30	0	
RADA-013	49	0	
RADA-038	30	0	

3.3 Calibration, Identification, and Quantitation

EPA6020A, ICP-MS Metals

Fifteen thallium records were qualified as estimated due to matrix interference, J/4.

Four thallium records were rejected due to matrix interference, R/4.

Table 6. Calibration (CAL), Identification (ID), and Quantitation Review Summary

Method Code	Total # of Records	# of Records Qualified for CAL, ID and Quantitation	Associated Samples Qualified
EPA160.2	4	0	
EPA300.0	20	0	
EPA365.2	4	0	
EPA6010A	264	0	
EPA6020A	746	19	DUN-IOU-00014, DUN-IOU-00015, DUN-IOU-00017, DUN- IOU-00018, DUN-IOU-00019, DUN-IOU-00020, DUN-IOU-00021, DUN-IOU-00022, DUN-IOU-00023, DUN-IOU-00024, DUN-IOU-00025, DUN-IOU-00034, DUN-IOU-00035, DUN-IOU-00037, DUN-IOU-00038, DUN-IOU-00039, DUN-IOU-00040, DUN-IOU-00044, DUN-IOU-00045
EPA7470A	12	0	
EPA7471B	10	0	
EPA8260B	20	0	
EPA900.0MOD	72	0	
EPA906.0MOD	10	0	
L3.21-10008	44	0	
RADA-001	4	0	
RADA-008	2	0	
RADA-009	2	0	
RADA-011	30	0	
RADA-013	49	0	
RADA-038	30	0	

3.4 Trip Blanks and Rinsate Blanks

Trip blanks and rinsate blanks were not required by the SAP.

3.5 Method Blanks

EPA6020A, ICP-MS Metals

Two iron records were qualified as estimated due to the detection of the analyte in the method blank, J/V.

Six iron records were qualified as non-detect due to the detection of the analyte in the method blank, U/V.

RADA-011, Uranium Series

Three uranium-235 records were qualified as non-detect due to the detection of the analyte in the method blank, U/V.

RADA-038, Uranium Series

Three thorium-230 records were qualified as estimated due to the detection of the analyte in the method blank, J/V.

Table 7. Method Blank (MB) Review Qualifier Summary

Method Code	Total # of MB Records	# of MB Records Qualified	Associated Samples Qualified
EPA6020A	746	8	DUN-IOU-00072, DUN-IOU-00073, DUN-IOU-00074, DUN-IOU-00075, DUN-IOU-00076, DUN-IOU-00078, DUN-IOU-00081, DUN-IOU-00082
RADA-011	30	3	PAOU10DCB0013, PAOU10DCB0017, PAOU10DCB0018
RADA-038	30	3	PAOU10DCB0011, PAOU10DCB0018, PAOU10DCB0019

3.6 Laboratory Duplicate RPD

All Laboratory Duplicate criteria for the reported analyses were within the recommended limits. No qualification was required.

Table 8. Laboratory Duplicate Qualifier Summary

Method Code	Total # of Duplicate Records	# of Duplicate Records Qualified	Associated Samples Qualified
EPA160.2	2	0	
EPA300.0	5	0	
EPA365.2	1	0	
EPA6010C	44	0	
EPA6020A	126	0	
EPA900.0MOD	10	0	
EPA906.0MOD	3	0	
L3.21-100008	4	0	
RADA-001	2	0	
RADA-008	1	0	
RADA-009	1	0	
RADA-011	6	0	
RADA-013	5	0	
RADA-038	3	0	

3.7 Field Duplicate RPD

All field duplicate RPD criteria for the reported analyses were within the recommended limits. No qualification was required.

Table 9. Field Duplicate Qualifier Summary

Method Code	Total # of Duplicate Records	# of Field Duplicate Records Qualified	Associated Samples Qualified
EPA6020A	78	0	
EPA900.0MOD	8	0	
L3.21-10008	4	0	

3.8 Matrix Spike Recovery

EPA6020A, ICP-MS Metals

Two barium records were qualified as estimated due to the MS/MSD recovery was outside the established control limits, J/11.

Two chromium records were qualified as approximate due to the MS/MSD recovery was outside the established control limits, UJ/11.

One cobalt record was qualified as estimated due to the MS/MSD recovery was outside the established control limits, J/11.

One copper record was qualified as estimated due to the MS/MSD recovery was outside the established control limits, J/11.

Two iron records were qualified as estimated due to the MS/MSD recovery was outside the established control limits, J/11.

Two manganese records were qualified as estimated due to the MS/MSD recovery was outside the established control limits, J/11.

One thallium record was qualified as estimated due to the MS/MSD recovery was outside the established control limits, J/11.

Table 10. Matrix Spike (MS) Recovery Qualifier Summary

Method Code	Total # of MS/MSD Records	# of MS/MSD Records Qualified	Associated Samples Qualified
EPA300.0	7	0	
EPA365.2	1	0	
EPA6010C	88	0	
EPA6020A	208	12	DUN-IOU-00019, DUN-IOU-00020
EPA7470A	2	0	
EPA7471B	2	0	
EPA8260B	160	0	
EPA900.0MOD	10	0	
EPA906.0MOD	3	0	
L3.21-10008	4	0	
RADA-008	1	0	

3.9 LCS Recovery

All LCS criteria for the reported analyses were within the recommended limits. No qualification was required.

Table 11. LCS Qualifier Summary

Method Code	Total # of LCS Records	# of LCS Records Qualified	Associated Samples Qualified
EPA160.2	2	0	
EPA300.0	7	0	
EPA365.2	2	0	
EPA6010C	44	0	
EPA6020A	134	0	
EPA7470A	4	0	
EPA7471B	1	0	
EPA8260B	80	0	
EPA900.0MOD	10	0	
EPA906.0MOD	4	0	
L3.21-10008	2	0	
RADA-001	2	0	
RADA-008	1	0	
RADA-009	2	0	
RADA-011	4	0	
RADA-013	3	0	
RADA-038	2	0	

3.10 Surrogate/Tracer Recovery

All Surrogate/Tracer recovery criteria for the reported analyses were within the recommended limits. No qualification was required.

Table 12. Surrogate/Tracer Recovery Qualifier Summary

Method Code	Total # of Surr/ Tracer Records	# of Surr Records Qualified	Associated Samples Qualified
EPA8260B	40	2	
RADA-009	2	0	
RADA-011	10	0	
RADA-038	10	0	

3.11 Split Samples Comparability.

Split samples were not taken.

4.0 DATA USABILITY

The analytical data evaluated in this usability report meets the DQOs and are considered usable for purposes outlined in the Sampling and Analysis Plan for the Wetland Area at Dunbarton Bay (NBN) in Support of Steel Creek Integrator Operable Unit (U), SGCP-SAP-2010-00007.

Four thallium environmental sample records were rejected. Rejected data should not be used. Qualification details are found in section 3.0, *Validation Findings*.

Appendix A-6:

Compact Disc – All Data

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Compact Disc

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APPENDIX B

Human Health Risk Assessment
and
PTSM Evaluation

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B.1 Introduction

The human health risk assessment (HHRA) and the principal threat source material (PTSM) evaluation for the Wetland Area at Dunbarton Bay (NBN) in support of the Steel Creek Integrator Operable Unit (IOU) are presented in this appendix. The unit is referred to as the Wetland Area at Dunbarton Bay although only a portion of the investigation area is classified as wetlands. From this point forward, the investigation area will be referred to as Dunbarton Bay. The Dunbarton Bay investigation area is down-gradient of the P-Area Ash Basin (PAB) and the P-007 Outfall, which are subunits of the P-Area Operable Unit (PAOU), where ash disposal activities have presented a pathway for the release of contaminants that may present a risk to human health and the environment. The wetlands portion of the investigation area is primarily located within the boundary of the Dunbarton Carolina bay (Figure 1-2).

Background

Similar to each reactor area at the Savannah River Site (SRS), P Area utilized a coal-fired powerhouse to generate steam and electricity, with coal ash (coal combustion products) produced as a result of boiler operations. In P Area, this ash was disposed within PAB via a sluice line. In 2010, ash was initially discovered outside the ash basin during the clearing of 35 acres surrounding the basin in preparation for an early removal action. Additional characterization efforts determined that the ash plume extends an additional 45 acres in the south-southwestern portion into a Carolina bay/wetland area named the Dunbarton Bay. Ash deposits in the wetlands range in depth from 1 to 3 ft. Since the ash is in a wetland area, Dunbarton Bay was administratively removed from the PAOU and placed in the Steel Creek IOU in 2010.

A HHRA and a principal threat source material (PTSM) evaluation have been performed for the PAB (SRNS, 2008). The following constituents were identified as HH RCOCs for a future industrial worker: arsenic (risk = 1.7E-05), potassium-40 (risk = 4.6E-05), radium-226 (+D) (risk = 1.5E-04), radium-228 (+D) (risk = 2.1E-05), thorium-228 (+D) (risk = 1.2E-05), and uranium-238 (+D) (risk = 2.3E-06). These HH RCOCs for the PAB resulted in a total cumulative risk of 2.5E-04. The residential scenario was not evaluated in the risk assessment. In addition, no PTSM (industrial worker risk >1E-03) was identified for the PAB. Since the source of the ash is essentially the same for both the PAB and Dunbarton Bay, it is expected that the concentrations of contaminants, as well as the risk associated with these constituents for human receptors (as appropriate), will be very similar. This information will be used as an additional line-of-evidence in the refinement of constituents of concern (COC) evaluation for Dunbarton Bay.

Data

There are two datasets associated with the characterization of Dunbarton Bay. The first dataset consisted of ten sample locations (PAB-116, -117, -119, -120, -153, -182, -183, -301, -302, -304) within Dunbarton Bay from the 0- to 1-ft ash/soil interval and two surface water samples (PAB-428, -429). These sample locations are depicted in Chapter 1, Figures 1-8 and 1-9. This data was collected in June 2010 and analyzed by General Engineering Laboratory. The data was verified and validated (V&V) and was used in a preliminary risk evaluation that was presented to the Core Team in August 2010 to assist in the determination of the administrative path forward for this area. This dataset has since been upgraded to definitive level data and is presented in the Data Usability Report (DUR) for this project (Appendix A).

A Sampling and Analysis Plan (SAP) was developed in 2011 to address data gaps identified in the original dataset (SRNS, 2011). These data gaps pertained primarily to the ecological risk assessment. More specifically, site specific biological field studies were initiated for metals associated with the ash media. The studies targeted both biotic (i.e., fauna) and abiotic (i.e., ash/soil) media. Although surface water was also intended to be sampled, Dunbarton Bay was dry due to regional draught conditions and no surface water samples were obtained. The Savannah River Ecology Laboratory (SREL) collected and analyzed the ash/soil and biota samples in 2011/2012. The data quality for this dataset is unverified and unvalidated (U&U).

In addition, four monitoring wells were installed to address the data uncertainty associated with the groundwater media and to determine if there is a threat of groundwater contamination migrating from Dunbarton Bay into other areas of SRS or off-site. The groundwater data is definitive level and was assessed in the DUR (Appendix A).

This HHRA uses the definitive level data that was collected in 2010 for the formal evaluation of the ash/soil media in Dunbarton Bay. This definitive level dataset is used as a basis for making a remedial decision at this unit from a human health risk perspective. The ash/soil media collected and analyzed by SREL in 2011/2012 does not have this high quality data pedigree, and therefore was not used in the HHRA. However, the SREL data was used in the weight-of-evidence evaluation to determine if the 2011/2012 ash/soil sample results could impact the conclusions of the HHRA. This evaluation is presented in Section B.2.4.

Two surface water samples were obtained in the 2010 sampling effort. One of these samples was within the Dunbarton Bay Carolina bay, and the second was in a drainage located outside of the bay. No surface water was present during the 2011 sampling event. Therefore the surface water media that is intermittently present within the Dunbarton Bay does not represent a sustainable exposure scenario that warrants a detailed risk evaluation. However, the surface water sampling results are compared to maximum contaminant levels (MCLs) since the wetland surface water could potentially drain into the headwaters of Meyers Branch in the Steel Creek IOU.

Consistent with past streamlining agreements, this HHRA does not formally evaluate (i.e., calculate the risk) for groundwater media. However a comparison of the sample results to MCLs is presented in Appendix D, the Contaminant Migration Analysis.

<u>Receptors</u>

The purpose of the HHRA is to evaluate the potential for adverse effects associated with exposure to constituents present at Dunbarton Bay. The assessment estimates the risk potential in the absence of any remedial action and provides a basis for determining whether or not remedial action is necessary. A streamlined approach that considers both standardized and site-specific receptor scenarios/exposure assumptions has been used for this evaluation. The receptors evaluated for the HHRA are described below. The HHRA evaluates the 0- to 1-ft interval for receptor exposure. The toxicity evaluation for all depth intervals is included in the PTSM evaluation.

The *future resident* receptor scenario evaluates long term risks to individuals expected to have unrestricted use of the unit as described in the protocol for *Human Health Receptors and Scenarios* (WSRC, 2006a). It assumes that residents hypothetically live on the unit and are exposed chronically to unit contaminants. The standard exposure assumptions are 30 years, 350 days per year, and 24 hours per day. The protocol for *Human Health Exposure Parameters* (WSRC, 2006a) describes the exposure assumptions and detailed input parameters used to derive the thresholds for a reasonable maximum exposure (RME) scenario. This receptor is routinely evaluated in operable unit (OU) program risk assessments performed by Area Completion Projects (ACP).

The *future industrial worker* receptor scenario is a standard United States Environmental Protection Agency (USEPA) scenario which addresses long-term-risks to workers who are exposed to unit contaminants within an industrial setting as described in the protocol for *Human Health Receptors and Scenarios* (WSRC, 2006a). The standard exposure assumptions are 25 years, 250 days per year, and 8 hours per day. The future industrial worker is an adult who hypothetically works on-unit in an outdoor setting for the majority of time. This receptor is routinely evaluated in OU program risk assessments performed by ACP.

The *onsite worker* receptor scenario involves a worker who is performing maintenance, collecting samples, or conducting research. The exposure assumptions for the onsite worker are 20 years, 150 days per year, and 8 hours per day. These site-specific assumptions are based on input provided by the SREL for a wetlands researcher. This receptor is routinely evaluated in the IOU program risk screening exercises (i.e., benchmark comparisons) performed by ACP.

The *adolescent trespasser* receptor scenario evaluates long-term risks to individuals expected to routinely trespass on the unit. This receptor would most likely consist of a local adolescent who would have access to the unit and would utilize the unit for wading, playing, or other recreational activities. The exposure assumptions for the adolescent trespasser are 10 years, 90 days per year, and 18 hours per day. This receptor is routinely evaluated in the IOU program risk screening exercises (i.e., benchmark comparisons) performed by ACP.

The primary exposure pathways for evaluation of human receptors include:

- Exposure to surface ash/soil media (0 to 1 ft) via incidental ingestion, dermal contact, inhalation of windblown dust, and external exposure from radionuclides.
- Exposure to surface water via ingestion, inhalation, dermal contact and external exposure from radionuclides (conservative drinking water standard comparison only).
- Exposure to groundwater via ingestion. A comparison of the sample results to MCLs is presented in Appendix D, the Contaminant Migration Analysis.

Sources of Risk-Based Threshold Values

The USEPA publishes regional screening levels (RSLs) for nonradiological constituents and preliminary remediation goals (PRGs) for radiological constituents that are risk-based concentrations (or activities) that can be used to evaluate potentially contaminated waste sites. RSLs and PRGs combine current USEPA toxicity values with standard exposure factors that represent RME conditions to estimate contaminant concentrations in soil that the agency considers protective of humans over a lifetime. The concentrations are based on direct exposure pathways for which generally accepted methods, models, and assumptions have been developed for specific land use conditions.

The *USEPA Regional Screening Levels* website (USEPA, 2011) is the source of RSLs used in this assessment. The website was accessed on February 27, 2012. The generic table published in November 2011 uses all default parameters for both the residential and industrial worker scenarios. A copy of the RSL table used in this evaluation for these standard receptors is provided as Attachment B-1 to this appendix. The RSLs for the onsite worker and adolescent trespasser scenarios were obtained by using the website calculator function to derive site-specific RSLs. The RSLs for these two scenarios are provided in Attachments B-2 and B-3, respectively.

The *USEPA Superfund Radionuclide Preliminary Remediation Goals for Superfund* website (USEPA, 2010) is the source of the PRGs used in this assessment. The website was also accessed on February 27, 2012. The PRGs for a residential scenario are obtained by using the website calculator function to derive site-specific PRGs. These site-specific PRG values are calculated by eliminating the fruit and vegetable consumption pathways as standard input assumptions and using all other default parameters (WSRC, 2006a). The residential PRG output from the radcalculator website is provided as Attachment B-4 to this appendix. The PRGs for an industrial worker scenario are obtained from the generic table that assumes all default parameters. A copy of the PRG table is provided as Attachment B-5 to this appendix. The PRGs for the onsite worker and adolescent trespasser scenarios were obtained by using the website calculator function to derive site-specific PRGs. The PRGs for these two scenarios are provided in Attachments B-6 and B-7, respectively.

It is important to note that the IOU benchmarks for site-specific receptors (i.e., onsite worker and adolescent trespasser) have been updated using the previously agreed upon exposure assumptions as inputs to the nonradiological and radiological USEPA website calculator functions to obtain the risk-based threshold values (i.e., RSLs and PRGs) used in this assessment.

B.2 Human Health Risk Assessment Process

The preliminary conceptual site model (CSM) for the Dunbarton Bay is provided in Chapter 1. Data used in this evaluation (verified and validated data) are provided in Appendix A of this document.

Selected radionuclides and radioactive decay chain products are designated in the PRG table with the suffix "+D" (plus daughters) to indicate that the cancer risk estimates for these constituents include contributions from their short-lived decay products, assuming equal activity concentrations (i.e., secular equilibrium) with the principal or parent nuclide in the environment. The "+D" indicates that associated decay products with half-lives less than six months are included in the PRG of the parent. The daughter products are not screened separately since they are considered in the parent(+D) PRG; the parent(+D) PRG is used in the risk evaluation.

The PRG website underwent a revision in August 2010, and a relatively minor issue has become apparent with this update. The website does not publish a thorium-228(+D) PRG. This oversight was relayed to the website administrator, who indicated that the table would be corrected in the next revision. For the evaluation of the residential scenario in this document, the thorium-228(+D) PRG from the previous version of the website was used (0.154 pCi/g). For the industrial worker scenario, the previous thorium(+D) PRG of 0.255 pCi/g (which assumed 225 days/year exposure) was modified to accommodate the extra 25 day exposure (i.e., 250 days/year exposure that was part of the August 2010 update) to obtain a value of 0.230 pCi/g. The uncertainty related to this apparent error in the website has no impact on the conclusions presented in this assessment.

B.2.1 Constituents of Potential Concern Screening: Ash/Soil Media

The process described in the protocol for *Human Health Constituents of Potential Concern* (WSRC, 2006a) is used to identify constituents of potential concern (COPCs) for Dunbarton Bay. It is summarized below:

- Compare unit maximum concentration in the 0- to 1-ft interval to residential soil RSL concentration or PRG activity for carcinogenic constituents.
- Compare unit maximum concentration in the 0- to 1-ft interval to 0.1 residential soil RSL concentrations for non-carcinogenic constituents.
- Compare unit maximum concentration of the naturally-occurring (non-anthropogenic) constituents in the 0- to 1-ft interval to 2X SRS average background soil concentration in the 0- to 1-ft soil interval (WSRC, 2006b; Appendix B-1).
- Constituents exceeding the residential soil RSL/PRG screening thresholds and the SRS background values are identified as COPCs and are carried forward to Step B.2.2.

B.2.2 Risk / Hazard Calculation: Ash/Soil Media

The process described in the protocol for *Human Health Constituents of Concern* (WSRC, 2006a) is used to identify COCs for Dunbarton Bay. It is summarized below:

- Segregate carcinogenic (risk) and non-carcinogenic (hazard) constituents. Risk and hazard estimates are based on the RME exposure point concentration (EPC), which is defined as the lesser of the maximum concentration and the 95% upper confidence limit (UCL) on the mean concentration.
- For carcinogens, the risk estimate = ([EPC] / [RSL or PRG]) x 1E-06: calculate the total chemical risk, total radiological risk, and total media risk. Constituents with an individual cancer risk ≥1E-06 are identified as COCs.
- For noncarcinogens, hazard estimate = ([EPC] / [RSL]): calculate the total media hazard index (HI). If the total media HI <1, then no COCs are identified. If the total media HI ≥1, then the constituents are segregated based on relevant target organs. Hazard Quotients (HQs) are summed according to target organs. Constituents are identified as COCs if the total organ HQ ≥0.1 and the total organ HI ≥1.
- Constituents identified as COCs are further evaluated in Step B.2.4.

B.2.3 MCL/RSL Comparison: Surface Water Media

Two surface water samples were obtained in the 2010 sampling effort. No surface water was present during the 2011 sampling event. Therefore the surface water media that is intermittently present within the Dunbarton Bay does not represent a sustainable exposure scenario that warrants a detailed risk evaluation. Although the surface water does not represent a reasonable or legitimate source of drinking water for human receptors, the sampling results (maximum concentration) are conservatively compared to MCLs (and tap water RSLs in the absence of a MCL). Constituents that exceed MCL/RSL thresholds are further evaluated in Step B.2.4.

B.2.4 Refinement of Constituents of Concern

A recommendation of whether or not a COC should be carried forward for further remedial evaluation is based on a thorough analysis of each COC. The uncertainty discussion is provided per the *Constituents of Concern Refinement Process Protocol* (WSRC, 2006a). SRS soil background concentrations used in this section are obtained from Appendix B-2 (all depths) of the *Background Soils Statistical Summary Report for Savannah River Site* (WSRC, 2006b), unless otherwise noted (i.e., cesium-137).

Results of the COPC screening (Step B.2.1), risk/hazard calculations to determine COCs (Step B.2.2), MCL/RSL comparison (Step B.2.3), and the refinement of COC analysis (Step B.2.4), are provided below for Dunbarton Bay.

Surface ash/soil data used in this assessment are provided in Appendix A, Table A-1. There are 10 locations (PAB-116, -117, -119, -120, -153, -182, -183, -301, -302, -304) within Dunbarton Bay that samples were obtained from the 0-1 ft ash/soil interval. Surface water data used in this assessment are provided in Appendix A, Table A-2 (PAB-428, -429).

Table B-1 identifies the following constituents as HH COPCs for the surface ash/soil media: arsenic, cobalt, iron, manganese, thallium, cesium-137(+D), potassium-40, radium-226(+D), radium-228(+D), thorium-228(+D), and uranium-238(+D).

Table B-2 identifies the following constituents as HH COCs for the future residential scenario: arsenic, cobalt, thallium, cesium-137(+D), potassium-40, radium-226(+D), radium-228(+D), thorium-228(+D), and uranium-238(+D).

Table B-3 identifies the following constituents as HH COCs for the future industrial worker scenario: arsenic, cesium-137(+D), potassium-40, radium-226(+D), radium-228(+D), thorium-228(+D), and uranium-238(+D).

Table B-4 identifies the following constituents as HH COCs for the site-specific onsite worker scenario: arsenic, cesium-137(+D), potassium-40, radium-226(+D), radium-228(+D), and thorium-228(+D).

Table B-5 identifies the following constituents as HH COCs for the site-specific adolescent trespasser scenario: arsenic, cesium-137(+D), potassium-40, radium-226(+D), radium-228(+D), and thorium-228(+D).

Table B-6 identifies arsenic as a surface water constituent exceeding the MCL and cobalt as a surface water constituent exceeding the tap water RSL.

B.2.4.1 Refinement of Constituents of Concern for Surface Ash/Soil Media

B.2.4.1.1 Arsenic Lines-of-Evidence Discussion

Arsenic is identified as a HH COC for the future resident (risk = 5.5E-05), future industrial worker (risk = 1.3E-05), onsite worker (risk = 6.5E-06) and adolescent trespasser (risk = 3.0E-06) scenarios. It was detected in 10 of 10 samples, with 2 sample results being estimated values. Concentrations ranged from

1.82 mg/kg to 33.6 mg/kg, with an average concentration of 14.8 mg/kg. Sample location PAB-120 had the highest detected concentration. The 95% UCL used in the risk estimate is 21.4 mg/kg.

The following table provides a comparison of the RSL threshold values for each of the receptor scenarios and the number of sample locations that exceeded each:

	Resident	**Industrial Worker**	**Onsite Worker**	**Adolescent Trespasser**
RSL *(mg/kg)*	0.39	1.60	3.32	7.10
Number of exceedences	10/10	10/10	7/10	7/10

Maximum concentration in SRS background soils is 22.9 mg/kg and the mean concentration is 2.23 mg/kg. Unit concentrations in the surface interval are greater than SRS background concentrations. Arsenic, naturally present in coal, may be concentrated in coal ash because it is not lost during combustion; thus, it is expected in Dunbarton Bay due to the ash material that has been deposited at this unit.

The HHRA for the P-Area Ash Basin (SRNS, 2008) identified arsenic as a RCOC for the industrial worker scenario with a risk estimate of 1.7E-05. It was detected in 18 of 18 surface ash samples, with four of the detects being estimated (i.e., "J" qualified) values. Concentrations ranged from 4.55 mg/kg to 59.7 mg/kg, with an average concentration of 20.4 mg/kg. The 95% UCL on the mean used in the risk calculation was 27.0 mg/kg. The concentration of arsenic and the corresponding risk estimate are slightly less in Dunbarton Bay than those measured at the PAB.

Arsenic is recommended for further remedial evaluation as a human health refined contaminant of concern (HH RCOC) in ash media for all four human receptor scenarios based on the following lines-of-evidence:

- Unit concentrations are higher than soil background concentrations at SRS.
- Its presence is consistent with the historical use of the unit.
- It was identified as a RCOC at the P-Area Ash Basin.

B.2.4.1.2 Cobalt Lines-of-Evidence Discussion

Cobalt is identified as a HH COC for the future resident (HQ = 0.2) scenario only. No sample results exceeded a hazard quotient (HQ) of one; it is identified as a COC based on the total blood organ hazard index (HI) (with thallium) that is greater than one. It was detected in 10 of 10 samples, with 1 sample result being an estimated value. Concentrations ranged from 0.43 mg/kg to 7.6 mg/kg, with an average concentration of 3.38 mg/kg. Sample location PAB-120 had the highest detected concentration. The 95% UCL used in the hazard estimate is 4.94 mg/kg.

The following table provides a comparison of the RSL threshold values for each of the receptor scenarios and the number of sample locations that exceeded each:

	Resident	**Industrial Worker**	**Onsite Worker**	**Adolescent Trespasser**
RSL (mg/kg)	23	300	506	540
Number of exceedences	0/10	0/10	0/10	0/10

Maximum concentration in SRS background soils is 5.04 mg/kg and the mean concentration is 0.698 mg/kg. Unit concentrations are slightly higher than soil background concentrations at SRS.

Cobalt is not traditionally known as by-product of coal combustion. However, all detections cannot be attributed to natural background conditions since unit concentrations of cobalt are slightly higher than SRS background concentrations.

The RSL for any of the four receptors evaluated was not exceeded in any samples. As stated previously, it is identified as a COC since it has a HQ >0.1 and is component of a total organ HI >1. Thallium is the other constituent that contributes to this blood total organ HI and is the primary driver in the calculation (HQ = 3.1). Therefore the uncertainty evaluation for cobalt relies heavily on the uncertainty evaluation for thallium. The maximum detected concentration of thallium is within the SRS background concentration, and is not recommended for further remedial evaluation as a RCOC (below).

The HHRA for the PAB (SRNS, 2008) did not identify cobalt as a RCOC.

Cobalt is not recommended for further remedial evaluation based on the following lines-of evidence:

- No sample results are greater than any of the four receptor RSLs evaluated, i.e., all HQs <1.
- The total organ HI calculation of 3.4 is dominated by thallium (HQ = 3.1). The cobalt contribution to this calculation is minimal (HQ = 0.2), and thallium is not being recommended for further remedial evaluation as a RCOC (below).
- It was not identified as a RCOC at the P-Area Ash Basin.

B.2.4.1.3 Thallium Lines-of-Evidence Discussion

Thallium is identified as a HH COC for the future resident (HQ = 3.1) scenario only. It is identified as a COC based on the total blood organ hazard index (with cobalt) that is greater than one. It was detected in 8 of 10 samples, with 5 sample results being estimated values. Concentrations ranged from nondetect (ND) to 3.67 mg/kg, with an average concentration of 1.67 mg/kg. Sample location PAB-183 had the highest detected concentration. The 95% UCL used in the risk estimate is 2.43 mg/kg.

The following table provides a comparison of the RSL threshold values for each of the receptor scenarios and the number of sample locations that exceeded each:

	Resident	Industrial Worker	Onsite Worker	Adolescent Trespasser
RSL *(mg/kg)*	0.78	10	17	18.3
Number of exceedences	7/10	0/10	0/10	0/10

Maximum concentration in SRS background soils is 8.13 mg/kg and the mean concentration is 1.47 mg/kg. Unit concentrations are within soil background concentrations at SRS.

Thallium is a naturally occurring constituent that is ubiquitous in SRS background soil. It is naturally present in coal, and may be concentrated in coal ash because it is not lost during combustion; thus, it is expected in Dunbarton Bay due to the ash material that has been deposited at this unit.

The HHRA for the PAB (SRNS, 2008) did not identify thallium as a RCOC.

Thallium is NOT recommended for further remedial evaluation based on the following:

- Thallium is a naturally occurring constituent that is common in SRS soil.
- Unit concentrations are within SRS background concentrations.
- It was not identified as a RCOC at the P-Area Ash Basin.

B.2.4.1.4 Cesium-137(+D) Lines-of-Evidence Discussion

Cesium-137(+D) is identified as a HH COC for the future resident (risk = 5.5E-05), future industrial worker (risk = 3.3E-05), onsite worker (risk = 1.7E-05) and adolescent trespasser (risk = 1.3E-05) scenarios. It was detected in 10 of 10 samples, with 1 sample result being an estimated value. Activities ranged from 0.0513 pCi/g to 5.19 pCi/g, with an average activity of 2.32 pCi/g. Sample location PAB-120 had the highest detected activity. The 95% UCL used in the risk estimate is 3.42 pCi/g.

The following table provides a comparison of the PRG threshold values for each of the receptor scenarios and the number of sample locations that exceeded each:

	Resident	**Industrial Worker**	**Onsite Worker**	**Adolescent Trespasser**
PRG (pCi/g)	0.0623	0.103	0.204	0.272
Number of exceedences	9/10	9/10	8/10	8/10

Cesium-137 is a result of nuclear fission- it does not occur naturally in soil. However, cesium-137 is common in SRS background soils as a result of fallout from nuclear weapons testing. Maximum concentration in natural SRS soils (WSRC, 2006a, Appendix B-1) is 3.3 pCi/g and mean concentration is 0.142 pCi/g. Unit activities are greater than SRS background activities.

The HHRA for the P-Area Ash Basin (SRNS, 2008) identified cesium-137(+D) as a COC for the industrial worker scenario with a risk estimate of 4.4E-06. It was detected in four of seven surface ash samples, with two detects being estimated (i.e., "J" qualified) values. Concentrations ranged from ND to 0.8 pCi/g, with an average concentration of 0.29 pCi/g. The 95% UCL on the mean used in the risk calculation was 0.489 pCi/g. Although produced in large quantities at SRS as a byproduct, its presence at P-Ash Basin was determined to unlikely be associated with the SRS radionuclide processing as there are no known historical activities at the P-Area Ash Basin that would have contaminated the area with process-related radionuclides. Its presence at this unit was more likely due to global atmospheric fallout. Therefore cesium-137(+D) was not identified as a HH RCOC for the P-Area Ash Basin.

However, the HHRA for the P007 Outfall (SRNS, 2008) identified cesium-137(+D) as a HH RCOC for the future industrial worker based on a risk estimate of 4.5E-04. It was detected in one of one surface ash samples. The concentration of the single detection was 50 pCi/g; this was the concentration used in the risk calculation. Its location and concentration at the P-007 Outfall indicates that it was a result of the process-related activities at P Area via discharge of a process sewer line from the P-Area Disassembly Basin, and not global atmospheric fallout. Therefore, it is likely that the source of the cesium-137(+D) at Dunbarton Bay is the P-007 Outfall material that was diverted along the west side of the PAB and into the wetland.

Cesium-137(+D) is recommended for further remedial evaluation as a HH RCOC in ash media for all four human receptor scenarios based on the following lines-of-evidence:

- Unit activities are above background fallout levels.
- Its presence is consistent with the history of the unit and the known discharge of the P Area process sewer lines to the P-007 Outfall which was subsequently diverted along the west side of the P Area Ash Basin to Dunbarton Bay.
- It was identified as a RCOC for the P-007 Outfall.

B.2.4.1.5 Potassium-40 Lines-of-Evidence Discussion

Potassium-40 is identified as a HH COC for the future resident (risk = 8.8E-05), future industrial worker (risk = 5.0E-05), onsite worker (risk = 2.4E-05) and adolescent trespasser (risk = 1.6E-05) scenarios. It was detected in 9 of 10 samples, with 0 sample results being estimated values. Activities ranged from ND to 16.4 pCi/g, with an average activity of 9.69 pCi/g. Sample location PAB-153 had the highest detected activity. The 95% UCL used in the risk estimate is 13.3 pCi/g.

The following table provides a comparison of the PRG threshold values for each of the receptor scenarios and the number of sample locations that exceeded each:

	Resident	Industrial Worker	Onsite Worker	Adolescent Trespasser
PRG (pCi/g)	0.150	0.265	0.552	0.819
Number of exceedences	9/10	9/10	9/10	9/10

Maximum activity in SRS background soils is 8.53 pCi/g and the mean activity is 1.26 pCi/g. Unit activities are greater than soil background activities at SRS. Potassium-40, naturally present in coal, may be concentrated in coal ash because it is not lost during combustion; thus, it is expected in Dunbarton Bay due to the ash material that has been deposited at this unit.

The HHRA for the P-Area Ash Basin (SRNS, 2008) identified potassium-40 as a HH RCOC for the future industrial worker based on a risk estimate of 4.6E-05. It was detected in seven of seven surface ash samples, with no detects being estimated (i.e., "J" qualified) values. Concentrations ranged from 7.6 pCi/g to 13.8 pCi/g, with an average concentration of 11.0 pCi/g. The 95% UCL on the mean used in the risk calculation was 12.4 pCi/g. The concentration of potassium-40 and the corresponding risk estimate are slightly higher in Dunbarton Bay than those measured at the PAB.

Potassium-40 is recommended for further remedial evaluation as a HH RCOC in ash media for all four human receptor scenarios based on the following lines-of-evidence:

- Unit concentrations are higher than soil background concentrations at SRS.
- Its presence is consistent with the historical use of the unit.
- It was identified as a RCOC for the P-Area Ash Basin.

B.2.4.1.6 Radium-226(+D) Lines-of-Evidence Discussion

Radium-226(+D) is identified as a HH COC for the future resident (risk = 1.9E-04), future industrial worker (risk = 1.1E-04), onsite worker (risk = 5.1E-05) and adolescent trespasser (risk = 3.5E-05) scenarios. It was detected in 10 of 10 samples, with 0 sample results being estimated values. Activities ranged from 0.347 pCi/g to 2.38 pCi/g, with an average activity of 1.74 pCi/g. Sample location PAB-183 had the highest detected activity. The maximum detected activity was used in the risk estimate since the 95% UCL was calculated to be higher than the maximum detected activity.

The following table provides a comparison of the PRG threshold values for each of the receptor scenarios and the number of sample locations that exceeded each:

	Resident	Industrial Worker	Onsite Worker	Adolescent Trespasser
PRG (pCi/g)	0.0127	0.0223	0.0464	0.0688
Number of exceedences	10/10	10/10	10/10	10/10

Maximum activity in SRS background soils is 1.74 pCi/g and the mean activity is 0.64 pCi/g. Unit activities are slightly greater than soil background activities at SRS. Radium-226, naturally present in coal, may be concentrated in coal ash because it is not lost during combustion; thus, it is expected in Dunbarton Bay due to the ash material that has been deposited at this unit.

The HHRA for the P-Area Ash Basin (SRNS, 2008) identified radium-226(+D) as a HH RCOC for the future industrial worker based on a risk estimate of 1.5E-04. It was detected in 11 of 11 surface ash samples, with no detects being estimated (i.e., "J" qualified) values. Concentrations ranged from 2.2 pCi/g to 5.4 pCi/g, with an average concentration of 3.35 pCi/g. The 95% UCL on the mean used in the risk calculation was 3.86 pCi/g. The concentration of radium-226 and the corresponding risk estimate are slightly less in Dunbarton Bay than those measured at the PAB.

Radium-226(+D) is recommended for further remedial evaluation as a HH RCOC in ash media for all four human receptor scenarios based on the following lines-of-evidence:

- Unit concentrations are higher than soil background concentrations at SRS.
- Its presence is consistent with the historical use of the unit.
- It was identified as a RCOC for the P-Area Ash Basin.

B.2.4.1.7 Radium-228(+D) Lines-of-Evidence Discussion

Radium-228(+D) is identified as a HH COC for the future resident (risk = 6.6E-05), future industrial worker (risk = 4.4E-05), onsite worker (risk = 2.5E-05) and adolescent trespasser (risk = 2.6E-05) scenarios. It was detected in 10 of 10 samples, with 1 sample result being an estimated value. Activities ranged from 0.389 pCi/g to 2.50 pCi/g, with an average activity of 1.70 pCi/g. Sample location PAB-182 had the highest detected activity. The 95% UCL used in the risk estimate is 2.11 pCi/g.

The following table provides a comparison of the PRG threshold values for each of the receptor scenarios and the number of sample locations that exceeded each:

	Resident	Industrial Worker	Onsite Worker	Adolescent Trespasser
PRG (pCi/g)	0.0319	0.0484	0.0843	0.0815
Number of exceedences	10/10	10/10	10/10	10/10

Maximum activity in SRS background soils is 6.75 pCi/g and the mean activity is 1.05 pCi/g. Unit activities are within soil background activities at SRS. Radium-228, naturally present in coal, may be concentrated in coal ash because it is not lost during combustion; thus, it is expected in Dunbarton Bay due to the ash material that has been deposited at this unit.

The HHRA for the P-Area Ash Basin (SRNS, 2008) identified radium-228(+D) as a HH RCOC for the future industrial worker based on a risk estimate of 2.1E-05. It was detected in seven of seven surface ash samples, with six detects being estimated (i.e., "J" qualified) values. Concentrations ranged from 1.09 pCi/g to 4.07 pCi/g, with an average concentration of 2.40 pCi/g. The 95% UCL on the mean used in the risk calculation was 3.17 pCi/g. The concentration of radium-228 in Dunbarton Bay is less than what was measured at the PAB.

Radium-228(+D) is not recommended for further remedial evaluation as a HH RCOC in ash media based on the following lines-of-evidence:

- Unit activities are within SRS background activities.
- It is a naturally occurring constituent that is common in SRS background soils.

- No distinction can be made between ash-related and background concentrations.

B.2.4.1.8 Thorium-228(+D) Lines of Evidence Discussion

Thorium-228(+D) is identified as a HH COC for the future resident (risk = 1.2E-05), future industrial worker (risk = 8.1E-06), onsite worker (risk = 4.1E-06) and adolescent trespasser (3.0E-06) scenarios. It was detected in 10 of 10 samples, with 0 sample results being estimated values. Activities ranged from 0.4 pCi/g to 2.21 pCi/g, with an average activity of 1.49 pCi/g. Sample location PAB-116 had the highest detected activity. The 95% UCL used in the risk estimate is 1.87 pCi/g.

The following table provides a comparison of the PRG threshold values for each of the receptor scenarios and the number of sample locations that exceeded each:

	Resident	**Industrial Worker**	**Onsite Worker**	**Adolescent Trespasser**
PRG (pCi/g)	0.154	0.230	0.460	0.627
Number of exceedences	10/10	10/10	9/10	9/10

Maximum activity in SRS background soils is 4.17 pCi/g and the mean activity is 1.11 pCi/g. Unit activities are within soil background activities at SRS. Thorium-228, naturally present in coal, may be concentrated in coal ash because it is not lost during combustion; thus, it is expected in Dunbarton Bay due to the ash material that has been deposited at this unit.

The HHRA for the P-Area Ash Basin (SRNS, 2008) identified thorium-228(+D) as a HH RCOC for the future industrial worker based on a risk estimate of 1.2E-05. It was detected in 11 of 11 surface ash samples, with three detects being estimated (i.e., "J" qualified) values. Concentrations ranged from 2.02 pCi/g to 3.94 pCi/g, with an average concentration of 2.65 pCi/g. The 95% UCL on the mean used in the risk calculation was 2.93 pCi/g. The concentration of thorium-228 and the corresponding risk estimate are slightly less in Dunbarton Bay than those measured at the PAB.

Thorium-228(+D) is not recommended for further remedial evaluation as a HH RCOC in ash media based on the following lines-of-evidence:

- Unit activities are within SRS background activities.
- It is a naturally occurring constituent that is common in SRS background soils.
- No distinction can be made between ash-related and background concentrations.

B.2.4.1.9 Uranium-238(+D) Lines-of-Evidence Discussion

Uranium-238(+D) is identified as a HH COC for the future resident (risk = 2.9E-06) and future industrial worker (risk = 1.4E-06) scenarios. It was detected in 10 of 10 samples, with 0 sample results being estimated values. Activities ranged from 0.294 pCi/g to 2.51 pCi/g, with an average activity of 1.62 pCi/g. Sample location PAB-301 had the highest detected activity. The 95% UCL used in the risk estimate is 2.07 pCi/g.

The following table provides a comparison of the PRG threshold values for each of the receptor scenarios and the number of sample locations that exceeded each:

	Resident	**Industrial Worker**	**Onsite Worker**	**Adolescent Trespasser**
PRG (pCi/g)	0.725	1.49	3.09	4.73
Number of exceedences	8/10	7/10	0/10	0/10

Maximum activity in SRS background soils is 1.9 pCi/g and the mean activity is 0.50 pCi/g. Unit activities are slightly greater than soil background activities at SRS. Uranium-238, naturally present in coal, may be concentrated in coal ash because it is not lost during combustion; thus, it is expected in Dunbarton Bay due to the ash material that has been deposited at this unit.

The HHRA for the P-Area Ash Basin (SRNS, 2008) identified uranium-238(+D) as a HH RCOC for the future industrial worker based on a risk estimate of 2.3E-06. It was detected in 11 of 11 surface ash samples, with none of the detects being estimated (i.e., "J" qualified) values. Concentrations ranged from 2.21 to 5.29 pCi/g, with an average concentration of 3.55 pCi/g. The 95% UCL on the mean used in the risk calculation was 4.10 pCi/g. The concentration of uranium-238 and the corresponding risk estimate are slightly less in Dunbarton Bay than those measured at the PAB.

Uranium-238(+D) is recommended for further remedial evaluation as a HH RCOC in ash media for the resident and industrial worker scenarios based on the following lines-of-evidence:

- Unit concentrations are higher than soil background concentrations at SRS.
- Its presence is consistent with the historical use of the unit.
- It was also identified as a RCOC for the P-Area Ash Basin.

B.2.4.2 Refinement of Constituents of Concern for Surface Water Media

B.2.4.2.1 Arsenic Lines-of-Evidence Discussion

Arsenic is identified as a COC in surface water media based on exceedence of the MCL. It was detected in 1 of 2 samples, with 0 sample results being estimated values. Concentrations ranged from ND to 46.5 µg/L. The MCL is 10 µg/L.

Two surface water samples were obtained in the 2010 sampling effort. One of these samples was within Dunbarton Bay, and the second was in a drainage located outside of the bay. No surface water was present during the 2011 sampling event, and it appears that the presence of surface water within the area is highly variable.

The samples were obtained from shallow pools of water less than six inches deep. Although a turbidity measurement is not available, it is very likely that there was a high degree of suspended solids that were present in the sample. Although arsenic is identified as a RCOC for the ash/soil media, the comparison to a drinking water standard is extremely conservative.

Arsenic is not recommended for further remedial evaluation as a HH RCOC in surface water media for the following reasons:

- Surface water within Dunbarton Bay is only intermittently present.
- The uncertainty regarding sample turbidity for the MCL exceedence could not be verified due to draught conditions.
- Comparison to a drinking water standard is overly conservative since the water that is occasionally present within Dunbarton Bay does not represent a reasonable, legitimate or sustainable source of drinking water for human receptors.

B.2.4.2.2 Cobalt Lines-of-Evidence Discussion

Cobalt is identified as a COC in surface water media based on exceedence of the tapwater RSL. It was detected in 2 of 2 samples, with 1 sample result being an estimated value. Concentrations ranged from 1.81 µg/L to 5.89 µg/L. The RSL is 4.7 µg/L.

Two surface water samples were obtained in the 2010 sampling effort. One of these samples was within Dunbarton Bay, and the second was in a drainage located outside of the bay. No surface water was present during the 2011 sampling event, and it appears that the presence of surface water within the area is highly variable.

The samples were obtained from shallow pools of water less than six inches deep. Although a turbidity measurement is not available, it is very likely that there was a high degree of suspended solids that were present in the sample. A comparison to a drinking water standard is extremely conservative.

Cobalt is not recommended for further remedial evaluation as a HH RCOC in surface water media for the following reasons:

- Surface water within Dunbarton Bay is only intermittently present.
- The uncertainty regarding sample turbidity for the RSL exceedence could not be verified due to draught conditions.
- Comparison to a drinking water standard is overly conservative since the water that is occasionally present within Dunbarton Bay does not represent a reasonable, legitimate or sustainable source of drinking water for human receptors.

B.2.5 Dunbarton Bay HHRA Conclusion

Residential scenario, 0- to 1-ft ash/soil interval: HH RCOCs include arsenic (risk = 5.5E-05), cesium-137(+D) (risk = 5.5E-05), potassium-40 (risk = 8.8E-05), radium-226(+D) (risk = 1.9E-04), and uranium-238(+D) (risk = 2.9E-06); the total cumulative risk is 3.9E-04.

Industrial worker scenario, 0- to 1-ft ash/soil interval: HH RCOCs include arsenic (risk = 1.3E-05), cesium-137(+D) (risk = 3.3E-05), potassium-40 (risk = 5.0E-05), radium-226(+D) (risk = 1.1E-04), and uranium-238(+D) (risk = 1.4E-06); the total cumulative risk is 2.1E-04.

IOU Onsite worker scenario, 0- to 1-ft ash/soil interval: HH RCOCs include arsenic (risk = 6.5E-06), cesium-137(+D) (risk = 1.7E-05), potassium-40 (risk = 2.4E-05), and radium-226(+D) (risk = 5.1E-05); the total cumulative risk is 9.9E-05.

Adolescent trespasser scenario, 0- to 1-ft ash/soil interval: HH RCOCs include arsenic (risk = 3.0E-06), cesium-137(+D) (risk = 1.3E-05), potassium-40 (risk = 1.6E-05), and radium-226(+D) (risk = 3.5E-05); the total cumulative risk is 6.7E-05.

No constituents are identified as RCOCs for the surface water media.

Comparison to PAB Evaluation

As a point of comparison, the following constituents were identified as HH RCOCs for a future industrial worker at the P Area Ash Basin (SRNS, 2008): arsenic (risk = 1.7E-05), potassium-40 (risk = 4.6E-05), radium-226(+D) (risk = 1.5E-04), radium-228(+D) (risk = 2.1E-05), thorium-228(+D) (risk = 1.2E-05), and uranium-238(+D) (risk = 2.3E-06). These HH RCOCs for the PAB resulted in a total cumulative risk of 2.5E-04.

In general, constituent concentrations are slightly higher at the PAB than Dunbarton Bay. Accordingly, radium-228 and thorium-228 were not identified as RCOCs in the Dunbarton Bay assessment since unit activities were well within SRS background activities.

Cesium-137 was identified as a RCOC at Dunbarton Bay. Although detected within the PAB, the maximum detected activity was with the background activity resulting from nuclear testing fallout, and it was not identified as a RCOC.

This HHRA uses a different set of risk-based threshold values (i.e., updated RSLs and PRGs) than what was used for the PAB risk assessment that was performed in the 2007/2008 time frame. For example, the PAB risk assessment used the USEPA 225 days per year default exposure assumption for the industrial worker. This assumption was modified in 2010 to be consistent with the RSL website and changed to 250 days per year. These extra 25 days of exposure lower the PRG threshold values by approximately 10% (i.e., more conservative). The Dunbarton Bay assessment used these more conservative threshold values.

Additional Evaluation of SREL Data

This section addresses the uncertainty of not using the surface ash/soil samples that were collected and analyzed by SREL in 2011/2012 in this HHRA. The dataset consists of metals only; these samples were not analyzed for any radiological constituents. The data is presented in Appendix A, Table A-4.

Aluminum was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 3,312 mg/kg to 18,461 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (6,970 mg/kg), it is well below the residential RSL of 77,000 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, aluminum would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Arsenic was identified as a RCOC for all four receptors evaluated in this HHRA. Arsenic was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 0.3 mg/kg to 40.9 mg/kg. The maximum detected concentration is higher than the maximum detected concentration from the 2010 dataset (33.6 mg/kg). The 95% UCL concentration used in the risk assessment was 21.4 mg/kg; the 95% UCL calculated for the SREL data is 24.3 mg/kg. This information can be used to provide a comparison of the risk estimates for each of the receptors:

Data	Risk			
	Resident	Industrial Worker	Onsite Worker	Adolescent Trespasser
2010 Data	5.5E-05	1.3E-05	6.5E-06	3.0E-06
SREL 2011/2012	6.2E-05	1.5E-05	7.4E-06	3.4E-06

Use of the SREL data would yield slightly higher risk estimates, and arsenic would still be identified as a RCOC for each receptor. This is not considered a significant issue since all of the risk-based thresholds (i.e., resident RSL = 0.39 mg/kg; industrial worker RSL = 1.6 mg/kg; onsite worker RSL = 3.3 mg/kg; adolescent trespasser = 7.1 mg/kg) are below the SRS background 95th percentile level (8.2 mg/kg) that would be established as the cleanup level. Therefore, arsenic is not an issue and use of the SREL data would not change the conclusions of the HHRA.

Barium was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 3.64 mg/kg to 294.5 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (144 mg/kg), it is well below the residential RSL of 15,000 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, barium would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Beryllium was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from

0.05 mg/kg to 5.28 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (2.08 mg/kg), it is well below the residential RSL of 160 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, beryllium would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Cadmium was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 8/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from ND to 0.249 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (0.224 mg/kg), it is well below the residential RSL of 70 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, cadmium would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Chromium was not identified as a RCOC for any of the receptors evaluated in this HHRA. The RSL tables identify various threshold values for chromium depending on the valence state. The USEPA recommends using the hexavalent chromium RSL when evaluating a waste site where chromium is an important contaminant/risk driver. The hexavalent chromium RSLs are 0.29 mg/kg for the resident receptor and 5.5 mg/kg for the industrial worker receptor. Although the HHRA used the most conservative RSL for hexavalent chromium in the screening evaluation, the chromium that is present at this site is naturally occurring in ash, and is not a result of chrome plating, manufacture of dyes, use as a leather tanning agent or wood preservatives, etc. Therefore hexavalent chromium is not expected to occur at Dunbarton Bay, and trivalent chromium is the most likely form of chromium.

Unspeciated (i.e., total) chromium was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 2.2 mg/kg to 28.3 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (15.4 mg/kg, total chromium), it is well below the residential RSL of 120,000 mg/kg for trivalent chromium, the most likely form of chromium at this waste unit. In addition, the maximum detected concentration of chromium (28.3 mg/kg) is less than what can be expected to occur in background soils at SRS (maximum = 54.3 mg/kg). Therefore, chromium would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Cobalt was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 0.16 mg/kg to 6.93 mg/kg. The maximum detected concentration is less than the maximum detected concentration that was used in the original dataset to perform the risk assessment (7.60 mg/kg), and it is well below the residential RSL of 23 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, cobalt would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Copper was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 0.7 mg/kg to 102.1 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (55.8 mg/kg), it is well below the residential RSL of 3,100 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, copper would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Iron was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 325 mg/kg to 20,025 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (14,200 mg/kg), it is well below the residential RSL of 55,000 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, iron would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Lead was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 7.5 mg/kg to 40.4 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (13.6 mg/kg), it is well below the residential RSL of 400 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, lead would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Manganese was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 1.9 mg/kg to 133.5 mg/kg. The maximum detected concentration is less than the maximum detected concentration that was used in the original dataset to perform the risk assessment (354 mg/kg), and it is well below the residential RSL of 1,800 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, manganese would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Mercury was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 0.005 mg/kg to 0.170 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (0.0773 mg/kg), it is well below the residential RSL of 10 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, mercury would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Nickel was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 9/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from ND to 29.6 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (12.6 mg/kg), it is well below the residential RSL of 1,500 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, nickel would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Selenium was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 9/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from ND to 8.39 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (5.4 mg/kg), it is well below the residential RSL of 390 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, selenium would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Silver was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 4/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from ND to 2.42 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (0.204 mg/kg), it is well below the residential RSL of 390 mg/kg. This is the most conservative risk-based threshold comparison. Therefore, silver would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Thallium was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 0.02 mg/kg to 1.43 mg/kg. The maximum detected concentration is less than the maximum detected concentration that was used in the original dataset to perform the risk assessment (3.67 mg/kg), and it is above the residential

RSL of 0.78 mg/kg. This is the most conservative risk-based threshold comparison. Thallium is a naturally occurring constituent that is ubiquitous in SRS background soil. Maximum concentration in SRS background soils is 8.13 mg/kg; unit concentrations are within SRS concentrations. Therefore, thallium would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Vanadium was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 10/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from 2.3 mg/kg to 57.6 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (25.8 mg/kg), it is well below the residential RSL of 390 mg/kg. This is the most conservative risk-based threshold comparison. Therefore vanadium would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Zinc was not identified as a RCOC for any of the receptors evaluated in this HHRA. It was detected in 9/10 SREL surface ash/soil samples within Dunbarton Bay. The concentrations ranged from ND to 78.5 mg/kg. Although the maximum detected concentration is higher than the maximum detected concentration that was used in the original dataset to perform the risk assessment (55.0 mg/kg), it is well below the residential RSL of 23,000 mg/kg. This is the most conservative risk-based threshold comparison. Therefore zinc would not be identified as a RCOC and use of the SREL data would not change the conclusions of the HHRA.

Additional uncertainty conclusion: Use of the 2011/2012 SREL data would not significantly alter the conclusions of this HHRA.

B.2.6 Human Health Risk Assessment Summary

Results of the human health risk assessment, including identification of RCOCs and corresponding risk/hazard estimates for the media of concern are provided below. The preliminary CSM was revised based on this assessment and is presented in Chapter 1, Figure 1-12.

Dunbarton Bay Human Health Risk Assessment Summary

Media	HH RCOCs	Risk Estimate	Total Cumulative Risk
Surface Ash/Soil	Resident		
	Arsenic	5.5E-05	3.9E-04
	Cesium-137(+D)	5.5E-05	
	Potassium-40	8.8E-05	
	Radium-226(+D)	1.9E-04	
	Uranium-238(+D)	2.9E-06	
	Industrial Worker		
	Arsenic	1.3E-05	2.1E-04
	Cesium-137(+D)	3.3E-05	
	Potassium-40	5.0E-05	
	Radium-226(+D)	1.1E-04	
	Uranium-238(+D)	1.4E-06	
	IOU Onsite Worker		
	Arsenic	6.5E-06	9.9E-05
	Cesium-137(+D)	1.7E-05	
	Potassium-40	2.4E-05	
	Radium-226(+D)	5.1E-05	
	Adolescent Trespasser		
	Arsenic	3.0E-06	6.7E-05
	Cesium-137(+D)	1.3E-05	
	Potassium-40	1.6E-05	
	Radium-226(+D)	3.5E-05	
Surface Water	Resident		
	None	Not applicable	Not applicable

B.3 PTSM (Toxicity) Evaluation Process

The concept of principal threat waste and low level threat waste as developed by the U.S. Environmental Protection Agency (USEPA) in the National Contingency Plan (NCP) (40 CFR 300.430(a)(1)(iii)) is to be applied on a site-specific basis when characterizing source material. Source materials are those materials that include or contain hazardous substances, pollutants, or contaminants that act as a reservoir for migration of contamination to groundwater, surface water, or air, or that act as a source for direct exposure (USEPA, 1991).

The determination of whether the source materials present at a waste unit would be classified as PTSM is based principally on the USEPA guidance document (USEPA, 1991). In this guidance, the USEPA defines principal threat wastes as "those source materials considered to be highly toxic or mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur." They include liquids and other highly mobile materials (e.g., materials that are released from surface soil due to volatilization, leaching, or surface runoff) or materials having high concentrations of toxic compounds. No "threshold level" of toxicity/risk has been established to equate to "principal threat." However, the guidance does state that treatment alternatives for source materials should generally be evaluated where the combined toxicity and mobility pose a potential risk of 1E-03 or greater.

The USEPA, SCDHEC, and USDOE evaluated the USEPA guidance with respect to toxicity and contaminant migration analyses performed at SRS. In practice, the SRS risk assessment and contaminant migration evaluations identify COCs associated with source material or impacted media and determine the associated risk or potential impact to groundwater. If threshold risk levels are exceeded or groundwater protection standards are predicted to be contravened in less than 1,000 years, these problems are identified and an evaluation of remedial alternatives is conducted in the Feasibility Study (FS). Since the risk assessment does not evaluate human receptor exposure to subsurface soils, further evaluation is needed to account for highly toxic source material or contaminated soils at depth that would result in unacceptable risk should exposure occur. However, since the existing program determines contaminant migration COCs for the entire soil column (vadose zone) in the remedial investigation, and addresses these COCs in the FS with evaluation of at least one treatment or removal alternative, the mobility aspect of PTSM is already being addressed as part of the RI/FS process. Therefore, a separate quantitative determination of PTSM based on mobility is not presented.

B.3.1 Determination of PTSM

Initially, a qualitative assessment of the source material(s) can be used to determine if the source material should be considered PTSM. These source materials would include containerized liquid wastes (e.g. drums) or non-aqueous phase liquids (NAPL) (e.g., perched dense NAPLs in the vadose zone), and highly toxic solid wastes such as PCB transformers or lead batteries.

In order to determine whether contaminated source material/soils/sediment should be preliminarily considered PTSM, a simple quantitative assessment evaluating the toxicity of the source is used as described in the following paragraphs.

In determining whether the source should be preliminarily considered PTSM, the evaluation considers the cumulative effects of both the potential risk from carcinogenic constituents and the adverse health effects from noncarcinogens to human receptors. Because the most likely future land use scenario for most SRS operable units being evaluated is industrial, the toxicity assessment of the source material is based on the potential exposure of a future industrial worker.

The source material is preliminarily considered to be PTSM if the cumulative risk exceeds one of the following toxicity threshold criteria:

- Carcinogens - greater than 1E-03 industrial worker risk
- Noncarcinogens – industrial worker hazard index (HI) greater than 10

In the preliminary screen, the unit maximum for every detected constituent for the ash/soil media from all depth intervals at Dunbarton Bay is determined and used as the EPC.

For carcinogens, the individual risk is calculated by multiplying the ratio of the EPC over the RSL or PRG by 1E-06. Each of these risks is summed to calculate the cumulative carcinogenic risk of the source. For noncarcinogens, an HQ is equal to the ratio of the EPC over the PRG. These HQs are summed to derive the cumulative HI. If the threshold criteria for PTSM are not exceeded based on a maximum concentration, then PTSM is not present and it is not necessary to evaluate further. If the threshold criteria are exceeded, the exposure point concentration used for the next comparison to PTSM thresholds is the 95% UCL on the mean. No PTSM threshold criteria were exceeded in the Dunbarton Bay PTSM evaluation.

An uncertainty analysis may be conducted to further evaluate the constituents and source(s) that exceed the PTSM toxicity criteria. This analysis is intended to help the Core Team make a final determination as to the presence of PTSM at the specific unit. Some examples where it may not be appropriate to identify the source term as PTSM include: 1) if the source defined as PTSM is of very limited extent or volume, 2) if the source term appears skewed based on a single value, 3) if a published toxicity value is undergoing additional evaluation, or 4) if the HI exceeds 10 based on the cumulative effects of noncarcinogens that effect different target organs. An uncertainty analysis is not warranted for the Dunbarton Bay PTSM evaluation.

B.3.2 Dunbarton Bay Results

Data used in this assessment are provided in Appendix A, Table A-1. For this evaluation, ten samples were collected from ten borings (PAB-116, -117, -119, -120, -153, -182, -183, -301, -302, -304).

The result of the PTSM evaluation is presented in Table B-7. No constituents are identified as PTSM for the ash/soil media (HI = 0.6; cumulative risk = 3.1E-04).

Conclusion: No PTSM RCOCs for ash/soil media at Dunbarton Bay.

The preliminary CSM was revised based on this evaluation and is presented in Chapter 1, Figure 1-12.

Additional Evaluation of SREL Data

This section addresses the impact of not using the surface/ash samples that were collected and analyzed by SREL in 2011/2012 in this PTSM Evaluation. The dataset consists of metals only; these samples were not analyzed for any radiological constituents.

Table B-8 presents a PTSM evaluation using the SREL data. No constituents are identified as PTSM for the ash/soil media (HI = 0.5; cumulative risk = 3.1E-05.) Therefore, the use of the 2011/2012 SREL data would not alter the conclusions of the PTSM Evaluation.

B.4 References

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Table B-1. Human Health COPC Screening Dunbarton Bay Surface Ash/Soil Media

Analyte	Detected Maximum Concentration[1]	Human Health Screening Value	Human Health Screening Value Source[2]	Exceeds Human Health Screening Value?	2X Average Background Concentration[3]	Exceeds 2X Average Background?[4]	COPC?[5]
***Inorganics** (mg/kg)*							
Aluminum	6.97E+03	7.7E+03	0.1xRSL	no	1.05E+04	no	no
Arsenic	3.36E+01	3.9E-01	RSL	YES	4.28E+00	YES	YES
Barium	1.44E+02	1.5E+03	0.1xRSL	no	3.91E+01	YES	no
Beryllium	2.08E+00	1.6E+01	0.1xRSL	no	2.89E-01	YES	no
Cadmium	2.24E-01	7.0E+00	0.1xRSL	no	4.83E-01	no	no
Calcium	2.09E+03	EN[6]	Nutrient	no	4.76E+02	YES	no
Chromium	1.54E+01	2.9E-01	RSL	YES	1.54E+01	no	no
Cobalt	7.60E+00	2.3E+00	0.1xRSL	YES	1.55E+00	YES	YES
Copper	5.58E+01	3.1E+02	0.1xRSL	no	4.34E+00	YES	no
Iron	1.42E+04	5.5E+03	0.1xRSL	YES	1.27E+04	YES	YES
Lead	1.36E+01	4.0E+01	0.1xRSL	no	1.03E+01	YES	no
Magnesium	3.60E+02	EN[6]	Nutrient	no	2.75E+02	YES	no
Manganese	3.54E+02	1.8E+02	0.1xRSL	YES	1.53E+02	YES	YES
Mercury	7.73E-02	1.0E+00	0.1xRSL	no	7.10E-02	YES	no
Nickel	1.26E+01	1.5E+02	0.1xRSL	no	3.48E+00	YES	no
Potassium	5.84E+02	EN[6]	Nutrient	no	2.16E+02	YES	no
Selenium	5.44E+00	3.9E+01	0.1xRSL	no	2.99E+00	YES	no
Silver	2.04E-01	3.9E+01	0.1xRSL	no	7.28E-01	no	no
Sodium	6.12E+01	EN[6]	Nutrient	no	4.02E+01	YES	no
Thallium	3.67E+00	7.8E-02	0.1xRSL	YES	3.12E+00	YES	YES
Vanadium	2.58E+01	3.9E+01	0.1xRSL	no	3.91E+01	no	no
Zinc	5.50E+01	2.3E+03	0.1xRSL	no	9.47E+00	YES	no
***Radionuclides** (pCi/g)*							
Cesium-137 (+D)	5.19E+00	6.23E-02	PRG	YES	2.84E-01	YES	YES
Potassium-40	1.64E+01	1.50E-01	PRG	YES	2.33E+00	YES	YES
Radium-226 (+D)	2.38E+00	1.27E-02	PRG	YES	1.37E+00	YES	YES
Radium-228 (+D)	2.50E+00	3.19E-02	PRG	YES	1.92E+00	YES	YES
Actinium-228[7]	2.50E+00	NA	NA	NA	NA	NA	no
Thorium-228 (+D)	2.21E+00	1.54E-01	PRG	YES	1.97E+00	YES	YES
Thorium-230	2.71E+00	3.74E+00	PRG	no	1.13E+00	YES	no
Thorium-232	2.29E+00	3.32E+00	PRG	no	1.80E+00	YES	no
Uranium-233/234	2.40E+00	4.69E+00	PRG	no	1.15E+00	YES	no
Uranium-235 (+D)	1.76E-01	1.94E-01	PRG	no	7.98E-02	YES	no
Uranium-238 (+D)	2.51E+00	7.25E-01	PRG	YES	1.01E+00	YES	YES

1. Maximum detected concentration from surface ash/soil interval (0-1 ft).
2. Nonradiological RSLs are residential soil values from the generic *USEPA Regional Screening Levels* (RSL) table, dated November 2011. Radiological PRGs are residential soil site-specific values derived using *USEPA Radionuclide Toxicity and Preliminary Remediation Goals (PRG) for Superfund* website calculator and eliminating the fruit and vegetable consumption pathways. All other inputs are default values. Websites accessed February 27, 2012.
3. Background screening values obtained from *Background Soils Statistical Summary Report for Savannah River Site*, ERD-EN-2005-0223, Rev. 1, 10/06, Appendix B-1.
4. For screening purposes, maximum concentration of the naturally-occurring (nonanthropogenic) constituents are compared to 2X average background concentration.
5. Constituents are identified as COPCs if the maximum detected concentration exceeds the human health screening value and the 2X average background concentration.
6. Essential nutrients are not identified as COPCs.
7. Ac-228 is a daughter product of the Ra-228; the activity of Ac-228 can be used to estimate the activity of Ra-228 since these constituents are in secular equilibrium. The Ra-228 (+D) PRG is then used in the screening comparison. A separate screen for Ac-228 is not performed since it is considered in the Ra-228 (+D) PRG calculation.

Table B-2. Human Health Risk/Hazard Calculation – Resident Dunbarton Bay Surface Ash/Soil Media

Analyte[1]	Exposure Point Concentration[2]	Residential RSL or PRG[3]	Residential Hazard Estimate[4]	Residential Risk Estimate[5]	COC?[6]
		Noncarcinogenic Hazard Estimate			
Inorganics (mg/kg)					
Arsenic	2.14E+01	2.2E+01	9.74E-01	----	no
Cobalt	4.94E+00	2.3E+01	2.15E-01	----	YES
Iron	9.43E+03	5.5E+04	1.71E-01	----	no
Manganese	2.11E+02	1.8E+03	1.17E-01	----	no
Thallium	2.43E+00	7.8E-01	3.11E+00	----	YES
		Total Media Hazard Index (HI) =	**4.59E+00**		
		Carcinogenic Risk Estimate			
Inorganics (mg/kg)					
Arsenic	2.14E+01	3.9E-01	----	5.49E-05	YES
Cobalt	4.94E+00	3.7E+02	----	1.34E-08	no
			Total Chemical Risk =	**5.49E-05**	
Radionuclides (pCi/g)					
Cesium-137 (+D)	3.42E+00	6.23E-02	----	5.49E-05	YES
Potassium-40	1.33E+01	1.50E-01	----	8.84E-05	YES
Radium-226 (+D)	2.38E+00	1.27E-02	----	1.87E-04	YES
Radium-228 (+D)	2.11E+00	3.19E-02	----	6.61E-05	YES
Thorium-228 (+D)	1.87E+00	1.54E-01	----	1.21E-05	YES
Uranium-238 (+D)	2.07E+00	7.25E-01	----	2.85E-06	YES
			Total Radionuclide Risk =	**4.12E-04**	
			Total Media Risk =	**4.67E-04**	

1. Analytes from Table B-1 that were identified as COPCs.
2. EPC = Reasonable maximum exposure (RME) exposure point concentration (EPC) is the lesser of the maximum concentration and the 95% upper confidence limit (UCL) on the mean.
3. Nonradiological RSLs are residential soil values from the generic *USEPA Regional Screening Levels (RSL)* table, dated November 2011. Radiological PRGs are residential soil site-specific values from the *USEPA Radionuclide Toxicity and Preliminary Remediation Goals (PRG) for Superfund* website calculator and eliminating the fruit and vegetable consumption pathways. All other inputs are default parameters. Websites accessed February 27, 2012.
4. Residential Hazard Estimate = EPC / RSL
5. Residential Risk Estimate = (EPC / PRG or RSL) x 1E-06
6. For noncarcinogens, no constituents are identified as COCs if the total media HI <1. If the total media HI ≥1, then the constituents are segregated based on relevant target organs. HQs are summed according to target organs (see table below). Constituents are identified as COCs if the total organ HQ ≥0.1 and the total organ HI >1. For carcinogens, constituents are identified as COCs if the individual cancer risk ≥1E-06.

Constituent	Target Organ	Residential HQ	
Arsenic	Skin	0.97	**Total Skin Target Organ Hazard Index**
Cobalt	Blood	0.22	
Thallium	Blood	3.11	
		3.33	**Total Blood Target Organ Hazard Index**
Iron	Liver	0.17	**Total Liver Target Organ Hazard Index**
Manganese	CNS	0.12	**Total CNS Target Organ Hazard Index**

Table B-3. Human Health Risk/Hazard Calculation - Industrial Worker Dunbarton Bay Surface Ash/Soil Media

Analyte[1]	Exposure Point Concentration[2]	Industrial RSL or PRG[3]	Industrial Hazard Estimate[4]	Industrial Risk Estimate[5]	COC?[6]
Noncarcinogenic Hazard Estimate					
Inorganics (mg/kg)					
Arsenic	2.14E+01	2.6E+02	8.24E-02	----	no
Cobalt	4.94E+00	3.0E+02	1.65E-02	----	no
Iron	9.43E+03	7.2E+05	1.31E-02	----	no
Manganese	2.11E+02	2.3E+04	9.02E-03	----	no
Thallium	2.43E+00	1.0E+01	2.43E-01	----	no
		Total Media Hazard Index (HI) =	**3.64E-01**		
Carcinogenic Risk Estimate					
Inorganics (mg/kg)					
Arsenic	2.14E+01	1.6E+00	----	1.34E-05	YES
Cobalt	4.94E+00	1.9E+03	----	2.60E-09	no
			Total Chemical Risk =	**1.34E-05**	
Radionuclides (pCi/g)					
Cesium-137 (+D)	3.42E+00	1.03E-01	----	3.32E-05	YES
Potassium-40	1.33E+01	2.65E-01	----	5.00E-05	YES
Radium-226 (+D)	2.38E+00	2.23E-02	----	1.07E-04	YES
Radium-228 (+D)	2.11E+00	4.84E-02	----	4.35E-05	YES
Thorium-228 (+D)	1.87E+00	2.30E-01	----	8.12E-06	YES
Uranium-238 (+D)	2.07E+00	1.49E+00	----	1.39E-06	YES
			Total Radionuclide Risk =	**2.43E-04**	
			Total Media Risk =	**2.56E-04**	

1. Analytes from Table B-1 that were identified as COPCs.
2. EPC = Reasonable maximum exposure (RME) exposure point concentration (EPC) is the lesser of the maximum concentration and the 95% upper confidence limit (UCL) on the mean.
3. Nonradiological RSLs are industrial worker soil values from the generic *USEPA Regional Screening Levels (RSL)*table, dated November 2011; radiological PRGs are industrial worker soil values from the generic *USEPA Radionuclide Toxicity and Preliminary Remediation Goals (PRG) for Superfund* website using all default inputs, dated August 2010. Websites accessed February 27, 2012.
4. Industrial Worker Hazard Estimate = EPC / RSL
5. Industrial Worker Risk Estimate = (EPC / PRG or RSL) x 1E-06
6. For noncarcinogens, no constituents are identified as COCs if the total media hazard index <1. For carcinogens, constituents are identified as COCs if the individual cancer risk ≥1E-06.

Table B-4. Human Health Risk/Hazard Calculation - Onsite Worker Dunbarton Bay Surface Ash/Soil Media

Analyte[1]	Exposure Point Concentration[2]	Onsite Worker RSL or PRG[3]	Onsite Worker Hazard Estimate[4]	Onsite Worker Risk Estimate[5]	COC?[6]
Noncarcinogenic Hazard Estimate					
Inorganics (mg/kg)					
Arsenic	2.14E+01	4.3E+02	5.04E-02	----	no
Cobalt	4.94E+00	5.1E+02	9.76E-03	----	no
Iron	9.43E+03	1.2E+06	7.93E-03	----	no
Manganese	2.11E+02	3.7E+04	5.66E-03	----	no
Thallium	2.43E+00	1.7E+01	1.43E-01	----	no
		Total Media Hazard Index (HI) =	**2.17E-01**		
Carcinogenic Risk Estimate					
Inorganics (mg/kg)					
Arsenic	2.14E+01	3.3E+00	----	6.45E-06	YES
Cobalt	4.94E+00	3.3E+03	----	1.48E-09	no
			Total Chemical Risk =	**6.45E-06**	
Radionuclides (pCi/g)					
Cesium-137 (+D)	3.42E+00	2.04E-01	----	1.68E-05	YES
Potassium-40	1.33E+01	5.52E-01	----	2.40E-05	YES
Radium-226 (+D)	2.38E+00	4.64E-02	----	5.13E-05	YES
Radium-228 (+D)	2.11E+00	8.43E-02	----	2.50E-05	YES
Thorium-228 (+D)	1.87E+00	4.60E-01	----	4.06E-06	YES
Uranium-238 (+D)	2.07E+00	3.09E+00	----	6.68E-07	no
			Total Radionuclide Risk =	**1.22E-04**	
			Total Media Risk =	**1.28E-04**	

1. Analytes from Table B-1 that were identified as COPCs.
2. EPC = Reasonable maximum exposure (RME) exposure point concentration (EPC) is the lesser of the maximum concentration and the 95% upper confidence limit (UCL) on the mean.
3. Nonradiological RSLs and radiological PRGs are site-specific values derived using the *USEPA Regional Screening Levels (RSL)* website, dated November 2011 and the *USEPA Radionuclide Toxicity and Preliminary Remediation Goals (PRG) for Superfund* website dated August 2010, respectively. Websites accessed February 27, 2012.
4. Onsite Worker Hazard Estimate = EPC / RSL
5. Onsite Worker Risk Estimate = (EPC / PRG or RSL) x 1E-06
6. For noncarcinogens, no constituents are identified as COCs if the total media hazard index <1. For carcinogens, constituents are identified as COCs if the individual cancer risk ≥1E-06.

Table B-5. Human Health Risk/Hazard Calculation - Adolescent Trespasser Dunbarton Bay Surface Ash/Soil Media

Analyte[1]	Exposure Point Concentration[2]	Trespasser RSL or PRG[3]	Trespasser Hazard Estimate[4]	Trespasser Risk Estimate[5]	COC?[6]
Noncarcinogenic Hazard Estimate					
Inorganics (mg/kg)					
Arsenic	2.14E+01	4.6E+02	4.71E-02	----	no
Cobalt	4.94E+00	5.4E+02	9.15E-03	----	no
Iron	9.43E+03	1.3E+06	7.37E-03	----	no
Manganese	2.11E+02	3.9E+04	5.48E-03	----	no
Thallium	2.43E+00	1.8E+01	1.33E-01	----	no
		Total Media Hazard Index (HI) =	**2.02E-01**		
Carcinogenic Risk Estimate					
Inorganics (mg/kg)					
Arsenic	2.14E+01	7.1E+00	----	3.02E-06	YES
Cobalt	4.94E+00	4.9E+03	----	1.00E-09	no
			Total Chemical Risk =	**3.02E-06**	
Radionuclides (pCi/g)					
Cesium-137 (+D)	3.42E+00	2.72E-01	----	1.26E-05	YES
Potassium-40	1.33E+01	8.19E-01	----	1.62E-05	YES
Radium-226 (+D)	2.38E+00	6.88E-02	----	3.46E-05	YES
Radium-228 (+D)	2.11E+00	8.15E-02	----	2.59E-05	YES
Thorium-228 (+D)	1.87E+00	6.27E-01	----	2.98E-06	YES
Uranium-238 (+D)	2.07E+00	4.73E+00	----	4.37E-07	no
			Total Radionuclide Risk =	**9.26E-05**	
			Total Media Risk =	**9.56E-05**	

1. Analytes from Table B-1 that were identified as COPCs.
2. EPC = Reasonable maximum exposure (RME) exposure point concentration (EPC) is the lesser of the maximum concentration and the 95% upper confidence limit (UCL) on the mean.
3. Nonradiological RSLs and radiological PRGs are site-specific values derived using the *USEPA Regional Screening Levels (RSL)* website, dated November 2011 and the *USEPA Radionuclide Toxicity and Preliminary Remediation Goals (PRG) for Superfund* website dated August 2010, respectively. Websites accessed February 27, 2012.
4. Trespasser Hazard Estimate = EPC / RSL
5. Trespasser Risk Estimate = (EPC / PRG or RSL) x 1E-06
6. For noncarcinogens, no constituents are identified as COCs if the total media hazard index <1. For carcinogens, constituents are identified as COCs if the individual cancer risk $\geq$1E-06.

Table B-6. Dunbarton Bay Surface Water Comparison to MCLs/ RSLs

ANALYTE	RESULT	UNITS	LAB QUAL	MCL	RESULT >MCL?	RSL	RESULT >RSL?
ALUMINUM	1,930	µg/L				16,000	no
ANTIMONY	4.54	µg/L	J	6	no		
ARSENIC	46.5	µg/L		10	**YES**		
BARIUM	93.5	µg/L		2,000	no		
CALCIUM[1]	17,300	µg/L					
CHROMIUM	7.65	µg/L		100	no		
COBALT	5.89	µg/L				4.7	**YES**
COPPER	5.07	µg/L	J	1,300	no		
IRON	9,550	µg/L				11,000	no
MAGNESIUM[1]	2,940	µg/L					
MANGANESE	277	µg/L				320	no
NICKEL	7.27	µg/L				300	no
NONVOLATILE BETA	9.6	pCi/L		4 mrem/yr	no		
POTASSIUM[1]	5,920	µg/L					
RADIUM-226	0.531	pCi/L	J	5	no		
SODIUM[1]	7,480	µg/L					
VANADIUM	25	µg/L				78	no
ZINC	33.1	µg/L				4,700	no

1. Calcium, magnesium, potassium and sodium are essential nutrients that do not have a MCL or a RSL.

Table B-7. PTSM Evaluation for Ash/Soil Media Dunbarton Bay (All Samples)

Constituent	Exposure Point Concentration[1]	Noncarcinogenic Hazard Estimate		Carcinogenic Risk Estimate	
		Industrial RSL[2]	Industrial Hazard Quotient (HQ) Estimate[3]	Industrial RSL or PRG[2]	Industrial Risk Estimate[4]
Inorganics *(mg/kg)*					
Aluminum	6.97E+03	9.9E+05	7.04E-03	----	----
Arsenic	3.36E+01	2.6E+02	1.29E-01	1.6E+00	2.10E-05
Barium	1.44E+02	1.9E+05	7.58E-04	----	----
Beryllium	2.08E+00	2.0E+03	1.04E-03	6.9E+03	3.01E-10
Cadmium	2.24E-01	8.0E+02	2.80E-04	9.3E+03	2.41E-11
Calcium	2.09E+03	EN	NA	----	----
Chromium	1.54E+01	1.5E+06	1.03E-05	5.6E+00	2.75E-06
Cobalt	7.60E+00	3.0E+02	2.53E-02	1.9E+03	4.00E-09
Copper	5.58E+01	4.1E+04	1.36E-03	----	----
Iron	1.42E+04	7.2E+05	1.97E-02	----	----
Lead	1.36E+01	8.0E+02	1.70E-02	----	----
Magnesium	3.60E+02	EN	NA	----	----
Manganese	3.54E+02	2.3E+04	1.54E-02	----	----
Mercury	7.73E-02	4.3E+01	1.80E-03	----	----
Nickel	1.26E+01	2.0E+04	6.30E-04	6.4E+04	1.97E-10
Potassium	5.84E+02	EN	NA	----	----
Selenium	5.44E+00	5.1E+03	1.07E-03	----	----
Silver	2.04E-01	5.1E+03	4.00E-05	----	----
Sodium	6.12E+01	EN	NA	----	----
Thallium	3.67E+00	1.0E+01	3.67E-01	----	----
Vanadium	2.58E+01	5.2E+03	4.96E-03	----	----
Zinc	5.50E+01	3.1E+05	1.77E-04	----	----
Radionuclides *(pCi/g)*					
Cesium-137 (+D)	5.19E+00	----	----	1.03E-01	5.04E-05
Potassium-40	1.64E+01	----	----	2.65E-01	6.19E-05
Radium-226 (+D)	2.38E+00	----	----	2.23E-02	1.07E-04
Radium-228 (+D)	2.50E+00	----	----	4.84E-02	5.17E-05
Actinium-228[5]	2.50E+00	----	----	NA	NA
Thorium-228 (+D)	2.21E+00	----	----	2.30E-01	9.61E-06
Thorium-230	2.71E+00	----	----	1.80E+01	1.51E-07
Thorium-232	2.29E+00	----	----	1.70E+01	1.35E-07
Uranium-233/234	2.40E+00	----	----	2.55E+01	9.41E-08
Uranium-235 (+D)	1.76E-01	----	----	3.48E-01	5.06E-07
Uranium-238 (+D)	2.51E+00	----	----	1.49E+00	1.68E-06
		Hazard Index	**5.93E-01**	Cumulative Risk	**3.07E-04**
		PTSM?[6]	**NO**	PTSM?[7]	**NO**

1. EPC = (exposure point concentration) maximum detected concentration in the all depths ash/soil interval.
2. Nonradiological RSLs are industrial worker soil values from the generic *USEPA Regional Screening Levels (RSL)* table, dated November 2011; radiological PRGs are composite worker soil values from the generic *USEPA Radionuclide Toxicity and Preliminary Remediation Goals (PRG) for Superfund* table, dated August 2010. Websites accessed February 27, 2012.
3. Hazard Estimate = exposure point concentration / RSL concentration
4. Risk Estimate = (exposure point concentration / PRG or RSL concentration) x 1E-06
5. Ac-228 is a daughter product of the Ra-228; the activity of Ac-228 can be used to estimate the activity of Ra-228 since these constituents are in secular equilibrium. The Ra-228 (+D) PRG is then used in the screening comparison. A separate screen for Ac-228 is not performed since it is considered in the Ra-228 (+D) PRG calculation.
6. Subunit potentially has PTSM if HI ≥10 for noncarcinogenic constituents.
7. Subunit potentially has PTSM if cumulative risk ≥1E-03 for carcinogenic constituents.

EN = essential nutrient
NA = not applicable

Table B-8. PTSM Evaluation for Ash/Soil Media Using SREL Samples Collected in 2011 - Dunbarton Bay

Constituent	Exposure Point Concentration[1]	Noncarcinogenic Hazard Estimate		Carcinogenic Risk Estimate	
		Industrial RSL[2]	Industrial Hazard Quotient (HQ) Estimate[3]	Industrial RSL or PRG[2]	Industrial Risk Estimate[4]
Inorganics (mg/kg)					
Aluminum	1.85E+04	9.9E+05	1.86E-02	----	----
Arsenic	4.09E+01	2.6E+02	1.57E-01	1.6E+00	2.56E-05
Barium	2.95E+02	1.9E+05	1.55E-03	----	----
Beryllium	5.28E+00	2.0E+03	2.64E-03	6.9E+03	7.65E-10
Cadmium	2.49E-01	8.0E+02	3.11E-04	9.3E+03	2.68E-11
Calcium	NA	EN	NA	----	----
Chromium	2.83E+01	1.5E+06	1.89E-05	5.6E+00	5.05E-06
Cobalt	6.93E+00	3.0E+02	2.31E-02	1.9E+03	3.65E-09
Copper	1.02E+02	4.1E+04	2.49E-03	----	----
Iron	2.00E+04	7.2E+05	2.78E-02	----	----
Lead	4.04E+01	8.0E+02	5.05E-02	----	----
Magnesium	NA	EN	NA	----	----
Manganese	1.34E+02	2.3E+04	5.80E-03	----	----
Mercury	1.70E-01	4.3E+01	3.95E-03	----	----
Nickel	2.96E+01	2.0E+04	1.48E-03	6.4E+04	4.63E-10
Potassium	NA	EN	NA	----	----
Selenium	8.39E+00	5.1E+03	1.65E-03	----	----
Silver	2.42E+00	5.1E+03	4.75E-04	----	----
Sodium	NA	EN	NA	----	----
Thallium	1.43E+00	1.0E+01	1.43E-01	----	----
Vanadium	5.76E+01	5.2E+03	1.11E-02	----	----
Zinc	7.85E+01	3.1E+05	2.53E-04	----	----
		Hazard Index	**4.52E-01**	Cumulative Risk	**3.06E-05**
		PTSM?[6]	**NO**	PTSM?[7]	**NO**

1 - EPC = (exposure point concentration) maximum detected concentration.
2 - Nonradiological RSLs are industrial worker soil values from the generic *USEPA Regional Screening Levels (RSL)* table, dated November 2011. Website accessed February 27, 2012.
3 - Hazard Estimate = exposure point concentration / RSL concentration
4 - Risk Estimate = (exposure point concentration / RSL concentration) x 1E-06
5 - Subunit potentially has PTSM if HI ≥ 10 for noncarcinogenic constituents.
6 - Subunit potentially has PTSM if cumulative risk ≥ 1E-03 for carcinogenic constituents.
EN = essential nutrient
NA = not applicable

Attachment B-1

USEPA Regional Screening Levels Table
RSLs for Default Resident and Default Industrial Worker Scenarios
(website accessed February 27, 2012)

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USEPA Regional Screening Levels Table *RSLs for Default Resident and Default Industrial Worker Scenarios* (website accessed February 27, 2012)

Toxicity and Chemical-Specific Information													Contaminant		Screening Levels											Protection of Ground	
SFO $(mg/kg\text{-}day)^{-1}$	Key	IUR $(\mu g/m^3)^{-1}$	Key	RfD_o (mg/kg-day)	Key	RfC_i (mg/m^3)	Key	VOC	Mutagen	GIABS	ABS	C_{sat} (mg/kg)	Analyte	CAS No.	Resident Soil (mg/kg)	Key	Industrial Soil (mg/kg)	Key	Resident Air $(\mu g/m^3)$	Key	Industrial Air $(\mu g/m^3)$	Key	Tapwater (µg/L)	Key	MCL (µg/L)	Risk-Based SSL (mg/kg)	MCL-Based SSL (mg/kg)
				1.0E+00	P	5.0E-03	P			1			Aluminum	7429-90-5	7.7E+04	n	9.9E+05	nm	5.2E+00	n	2.2E+01	n	1.6E+04	n		2.3E+04	
1.5E+00	I	4.3E-03	I	3.0E-04	I	1.5E-05	C			1	0.03		Arsenic, Inorganic	7440-38-2	3.9E-01	c*	1.6E+00	c	5.7E-04	c*	2.9E-03	c*	4.5E-02	c	1.0E+01	1.3E-03	2.9E-01
				2.0E-01	I	5.0E-04	H			0.07			Barium	7440-39-3	1.5E+04	n	1.9E+05	nm	5.2E-01	n	2.2E+00	n	2.9E+03	n	2.0E+03	1.2E+02	8.2E+01
		2.4E-03	I	2.0E-03	I	2.0E-05	I			0.007			Beryllium and compounds	7440-41-7	1.6E+02	n	2.0E+03	n	1.0E-03	c*	5.1E-03	c*	1.6E+01	n	4.0E+00	1.3E+01	3.2E+00
		1.8E-03	I	1.0E-03	I	2.0E-05	C			0.025	0.001		Cadmium (Diet)	7440-43-9	7.0E+01	n	8.0E+02	n									
				1.5E+00	I					0.013			Chromium(III), Insoluble Salts	16065-83-1	1.2E+05	nm	1.5E+06	nm					1.6E+04	n		2.8E+07	
		9.0E-03	P	3.0E-04	P	6.0E-06	P			1			Cobalt	7440-48-4	2.3E+01	n	3.0E+02	n	2.7E-04	c*	1.4E-03	c*	4.7E+00	n		2.1E-01	
				4.0E-02	H					1			Copper	7440-50-8	3.1E+03	n	4.1E+04	n					6.2E+02	n	1.3E+03	2.2E+01	4.6E+01
				7.0E-01	P					1			Iron	7439-89-6	5.5E+04	n	7.2E+05	nm					1.1E+04	n		2.7E+02	
										1			Lead and Compounds	7439-92-1	4.0E+02	n	8.0E+02	n							1.5E+01		1.4E+01
				2.4E-02	S	5.0E-05	I			0.04			Manganese (Non-diet)	7439-96-5	1.8E+03	n	2.3E+04	n	5.2E-02	n	2.2E-01	n	3.2E+02	n		2.1E+01	
						3.0E-04	I	V		1		3.1E+00	Mercury (elemental)	7439-97-6	1.0E+01	ns	4.3E+01	ns	3.1E-01	n	1.3E+00	n	6.3E-01	n	2.0E+00	3.3E-02	1.0E-01
		2.6E-04	C	2.0E-02	I	9.0E-05	A			0.04			Nickel Soluble Salts	7440-02-0	1.5E+03	n	2.0E+04	n	9.4E-03	c*	4.7E-02	c**	3.0E+02	n		2.0E+01	
				5.0E-03	I	2.0E-02	C			1			Selenium	7782-49-2	3.9E+02	n	5.1E+03	n	2.1E+01	n	8.8E+01	n	7.8E+01	n	5.0E+01	4.0E-01	2.6E-01
				5.0E-03	I					0.04			Silver	7440-22-4	3.9E+02	n	5.1E+03	n					7.1E+01	n		6.0E-01	
				6.0E-01	I					1			Strontium, Stable	7440-24-6	4.7E+04	n	6.1E+05	nm					9.3E+03	n		3.3E+02	
				1.0E-05	X					1			Thallium (Soluble Salts)	7440-28-0	7.8E-01	n	1.0E+01	n					1.6E-01	n	2.0E+00	1.1E-02	1.4E-01
				3.0E-03	I	3.0E-04	A			1			Uranium (Soluble Salts)	NA	2.3E+02	n	3.1E+03	n	3.1E-01	n	1.3E+00	n	4.7E+01	n	3.0E+01	2.1E+01	1.4E+01
				5.0E-03	S					1			Vanadium and Compounds	NA	3.9E+02	n	5.2E+03	n					7.8E+01	n		7.8E+01	
				3.0E-01	I					1			Zinc and Compounds	7440-66-6	2.3E+04	n	3.1E+05	nm					4.7E+03	n		2.9E+02	
5.0E-01	J	8.4E-02	S	3.0E-03	I	1.0E-04	I		M	0.025			Chromium(VI)	18540-29-9	2.9E-01	c	5.6E+00	c	1.1E-05	c	1.5E-04	c	3.1E-02	c		5.9E-04	

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Attachment B-2

USEPA Regional Screening Levels
Table Site-Specific RSLs for Onsite Worker Scenario
(website accessed February 27, 2012)

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Site-Specific Onsite Worker Equation Inputs for Soil **Variable**	**Value**
TR (target cancer risk) unitless	0.000001
THQ (target hazard quotient) unitless	1
AT_{ow} (averaging time)	365
EF_{ow} (exposure frequency) d/yr	150
ED_{ow} (exposure duration) yr	20
ET_{ow} (exposure time) hr	8
LT (lifetime) yr	70
BW_{ow} (body weight)	70
IR_{ow} (soil ingestion rate) mg/day	100
SA_{ow} (surface area) cm^2/day	3,300
AF_{ow} (skin adhereence factor) mg/cm^2	0.2

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Site-Specific
Onsite Worker Risk-Based Screening Levels for Soil

Chemical	CAS Number	Ingestion SF *(mg/kg-day)*$^{-1}$	Inhalation Unit Risk *(ug/m^3)*$^{-1}$	Chronic RfD *(mg/kg-day)*	Chronic RfC *(mg/m^3)*	GIABS	ABS	Particulate Emission Factor	Ingestion SL TR=1.0E-6 *(mg/kg)*	Dermal SL TR=1.0E-6 *(mg/kg)*	Inhalation SL TR=1.0E-6 *(mg/kg)*	Carcinogenic SL TR=1.0E-6 *(mg/kg)*	Ingestion SL HQ=1 *(mg/kg)*	Dermal SL HQ=1 *(mg/kg)*	Inhalation SL HQ=1 *(mg/kg)*	NonCarcinogenic SL HI=1 *(mg/kg)*	Screening Level *(mg/kg)*
Arsenic, Inorganic	7440-38-2	1.50E+00	4.30E-03	3.00E-04	1.50E-05	1	0.03	1.17E+09	3.97E+00	2.01E+01	6.98E+03	3.32E+00	5.11E+02	2.58E+03	1.29E+05	4.25E+02	3.32E+00 ca
Cobalt	7440-48-4	-	9.00E-03	3.00E-04	6.00E-06	1	-	1.17E+09	-	-	3.34E+03	3.34E+03	5.11E+02	-	5.15E+04	5.06E+02	5.06E+02 nc
Iron	7439-89-6	-	-	7.00E-01	-	1	-	1.17E+09	-	-	-	-	1.19E+06	-	-	1.19E+06	1.19E+06 max
Lead and Compounds	7439-92-1	-	-	-	-	1	-	1.17E+09	-	-	-	-	-	-	-	8.00E+02	8.00E+02 nc
Manganese (Non-diet)	7439-96-5	-	-	2.40E-02	5.00E-05	0.04	-	1.17E+09	-	-	-	-	4.09E+04	-	4.29E+05	3.73E+04	3.73E+04 nc
Thallium (Soluble Salts)	7440-28-0	-	-	1.00E-05	-	1	-	1.17E+09	-	-	-	-	1.70E+01	-	-	1.70E+01	1.70E+01 nc
Vanadium and Compounds	NA	-	-	5.04E-03	-	1	-	1.17E+09	-	-	-	-	8.58E+03	-	-	8.58E+03	8.58E+03 nc

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Attachment B-3

USEPA Regional Screening Levels
Table Site-Specific RSLs for Adolescent Trespasser Scenario
(website accessed February 27, 2012)

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Site-Specific Adolescent Trespasser Equation Inputs for Soil **Variable**	**Value**
TR (target cancer risk) *unitless*	0.000001
THQ (target hazard quotient) *unitless*	1
AT_{ow} (averaging time)	365
EF_{ow} (exposure frequency) *d/yr*	90
ED_{ow} (exposure duration) *yr*	10
ET_{ow} (exposure time) *hr*	18
LT (lifetime) *yr*	70
BW_{ow} (body weight)	45
IR_{ow} (soil ingestion rate) *mg/day*	100
SA_{ow} (surface area) *cm^2/day*	3,300
AF_{ow} (skin adhereence factor) *mg/cm^2*	0.2
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Site-Specific
Adolescent Trespasser Risk-Based Screening Levels for Soil

Chemical	CAS Number	Ingestion SF *(mg/kg-day)$^{-1}$*	Inhalation Unit Risk *(ug/m^3)$^{-1}$*	Chronic RfD *(mg/kg-day)*	Chronic RfC *(mg/m^3)*	GIABS	ABS	Particulate Emission Factor *(m^3/kg)*	Ingestion SL TR=1.0E-6 *(mg/kg)*	Dermal SL TR=1.0E-6 *(mg/kg)*	Inhalation SL TR=1.0E-6 *(mg/kg)*	Carcinogenic SL TR=1.0E-6 *(mg/kg)*	Ingestion SL HQ=1 *(mg/kg)*	Dermal SL HQ=1 *(mg/kg)*	Inhalation SL HQ=1 *(mg/kg)*	Noncarcinogenic SL HI=1 *(mg/kg)*	Screening Level *(mg/kg)*
Arsenic, Inorganic	7440-38-2	1.50E+00	4.30E-03	3.00E-04	1.50E-05	1	0.03	1.17E+09	8.52E+00	4.30E+01	1.03E+04	7.10E+00	5.48E+02	2.77E+03	9.53E+04	4.55E+02	7.10E+00 ca*
Cobalt	7440-48-4	-	9.00E-03	3.00E-04	6.00E-06	1	-	1.17E+09	-	-	4.94E+03	4.94E+03	5.48E+02	-	3.81E+04	5.40E+02	5.40E+02 nc
Iron	7439-89-6	-	-	7.00E-01	-	1	-	1.17E+09	-	-	-	-	1.28E+06	-	-	1.28E+06	1.28E+06 max
Lead and Compounds	7439-92-1	-	-	-	-	1	-	1.17E+09	-	-	-	-	-	-	-	8.00E+02	8.00E+02 nc
Manganese (Non-diet)	7439-96-5	-	-	2.40E-02	5.00E-05	0.04	-	1.17E+09	-	-	-	-	4.38E+04	-	3.18E+05	3.85E+04	3.85E+04 nc
Thallium (Soluble Salts)	7440-28-0	-	-	1.00E-05	-	1	-	1.17E+09	-	-	-	-	1.83E+01	-	-	1.83E+01	1.83E+01 nc
Vanadium and Compounds	NA	-	-	5.04E-03	-	1	-	1.17E+09	-	-	-	-	9.20E+03	-	-	9.20E+03	9.20E+03 nc

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Attachment B-4

USEPA Superfund Radionuclide Preliminary Goals for Superfund — Site-Specific PRGs for Residential Scenario (website accessed February 27, 2012)

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Site-Specific Resident Equation Inputs for Soil Variable		Value	Site-Specific Resident Equation Inputs for Soil Variable		Value
Slab size for ACF (area correction factor)	*m^2*	10,000	$IRF_{r\text{-}a}$ (fruit consumption rate - resident adult)	*mg/day*	0
TR (target cancer risk)	*unitless*	0.000001	$IRF_{r\text{-}c}$ (fruit consumption rate - resident child)	*mg/day*	0
t_r (time - resident)	*yr*	30	$IRV_{r\text{-}a}$ (vegetable consumption rate - resident adult)	*kg/yr*	0
ED_r (exposure duration - resident)	*yr*	30	$IRV_{r\text{-}c}$ (vegetable consumption rate - resident child)	*kg/yr*	0
ET_r (exposure time - resident)	*hr/day*	24	$IRA_{r\text{-}a}$ (inhalation rate - resident adult)	*m^3/day*	20
$ET_{r\text{-}o}$ (exposure time - outdoor resident)	*hr/hr*	0.073	$IRA_{r\text{-}c}$ (inhalation rate - resident child)	*m^3/day*	10
$ET_{r\text{-}i}$ (exposure time - indoor resident)	*hr/hr*	0.684	$IFF_{r\text{-}adj}$ (age-adjusted fruit ingestion factor - resident)	*kg/yr*	0
$ED_{r\text{-}c}$ (exposure duration - resident child)	*yr*	6	$IFV_{r\text{-}adj}$ (age-adjusted vegetable ingestion factor - resident)	*kg/yr*	0
$ED_{r\text{-}a}$ (exposure duration - resident adult)	*yr*	24	$IFS_{r\text{-}adj}$ (age-adjusted soil ingestion factor - resident)	*mg/day*	120
EF_r (exposure frequency - resident)	*day/yr*	350	$IFA_{r\text{-}adj}$ (age-adjusted soil inhalation factor - resident)	*m^3/day*	18
$IRS_{r\text{-}a}$ (soil intake rate - resident adult)	*mg/day*	100	GSF_i (gamma shielding factor - indoor)	*unitless*	0.4
$IRS_{r\text{-}c}$ (soil intake rate - resident child)	*mg/day*	200	CPF_r (contaminated plant fraction)	*unitless*	0.25
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Site-Specific
Resident PRGs for Soil

Isotope	ICRP Lung Absorption Type	Inhalation Slope Factor *(risk/pCi)*	External Exposure Slope Factor *(risk/yr per pCi/g)*	Food Slope Factor *(risk/pCi)*	Soil Ingestion Slope Factor *(risk/pCi)*	Particulate Emission Factor *(m^3/kg)*	Lambda	Area Correction Factor	Wet Soil-to-Plant Transfer Factor	Ingestion PRG *(pCi/g)*	Inhalation PRG *(pCi/g)*	External Exposure PRG *(pCi/g)*	Produce Ingestion PRG *(pCi/g)*	Total PRG *(pCi/g)*
Cs-137+D	F	1.19E-11	2.54E-06	3.74E-11	4.33E-11	1.17E+09	2.31E-02	8.77E-01	4.00E-02	2.54E+01	7.24E+05	6.24E-02	-	6.23E-02
K-40	F	1.03E-11	7.98E-07	3.43E-11	6.18E-11	1.17E+09	5.41E-10	8.26E-01	3.00E-01	1.28E+01	6.04E+05	1.52E-01	-	1.50E-01
Ra-226+D	M	1.16E-08	8.49E-06	5.15E-10	7.30E-10	1.17E+09	4.33E-04	9.26E-01	4.00E-02	1.09E+00	5.39E+02	1.28E-02	-	1.27E-02
Ra-228+D	M	5.23E-09	1.23E-05	1.43E-09	2.29E-09	1.17E+09	1.21E-01	9.26E-01	4.00E-02	1.29E+00	4.42E+03	3.27E-02	-	3.19E-02
Th-228	S	1.32E-07	5.59E-09	1.48E-10	2.89E-10	1.17E+09	3.62E-01	9.80E-01	1.00E-03	2.98E+01	5.12E+02	1.99E+02	-	2.47E+01
Th-230	S	2.85E-08	8.19E-10	1.19E-10	2.02E-10	1.17E+09	9.00E-06	9.97E-01	1.00E-03	3.93E+00	2.18E+02	1.23E+02	-	3.74E+00
Th-232	S	4.33E-08	3.42E-10	1.33E-10	2.31E-10	1.17E+09	4.93E-11	9.98E-01	1.00E-03	3.44E+00	1.44E+02	2.94E+02	-	3.32E+00
U-233	M	1.16E-08	9.82E-10	9.69E-11	1.60E-10	1.17E+09	4.37E-06	9.98E-01	2.50E-03	4.96E+00	5.36E+02	1.02E+02	-	4.69E+00
U-234	M	1.14E-08	2.52E-10	9.55E-11	1.58E-10	1.17E+09	2.83E-06	9.98E-01	2.50E-03	5.02E+00	5.45E+02	3.99E+02	-	4.92E+00
U-235	M	1.01E-08	5.19E-07	9.44E-11	1.57E-10	1.17E+09	9.85E-10	9.60E-01	2.50E-03	5.06E+00	6.15E+02	2.01E-01	-	1.94E-01
U-235+D	M	1.01E-08	-	9.76E-11	1.63E-10	1.17E+09	9.85E-10	9.60E-01	2.50E-03	4.87E+00	6.15E+02	-	-	4.83E+00
U-238+D	M	9.35E-09	1.14E-07	1.21E-10	2.10E-10	1.17E+09	1.55E-10	9.79E-01	2.50E-03	3.78E+00	6.65E+02	8.99E-01	-	7.25E-01

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Attachment B-5

USEPA Superfund Radionuclide Preliminary Goals
for Superfund — Default PRGs for Industrial Worker Scenario
(website accessed February 27, 2012)

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Default Composite Worker Equation Inputs for Soil Variable	Value
Slab size for ACF (area correction factor) m^2	Default (isotope-specific)
TR (target cancer risk) unitless	0.000001
t_w (time - composite worker) yr	25
ED_w (exposure duration - composite worker) yr	25
ET_w (exposure time - composite worker) hr/day	8
EF_w (exposure frequency - composite worker) day/yr	250
IR_w (soil intake rate - composite worker) mg/day	100
IRA_w (inhalation rate - composite worker) m^3/day	60
GSF_o (gamma shielding factor - outdoor) unitless	1
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Default
Composite Worker PRGs for Soil

Isotope	ICRP Lung Absorption Type	Inhalation Slope Factor *(risk/pCi)*	External Exposure Slope Factor *(risk/yr per pCi/g)*	Adult Soil Ingestion Slope Factor *(risk/pCi)*	Particulate Emission Factor *(m^3/kg)*	Lambda	Area Correction Factor	Ingestion PRG *(pCi/g)*	Inhalation PRG *(pCi/g)*	External Exposure PRG *(pCi/g)*	Total PRG *(pCi/g)*
Cs-137+D	F	1.19E-11	2.54E-06	3.17E-11	1.36E+09	2.31E-02	8.77E-01	6.64E+01	1.20E+06	1.04E-01	1.03E-01
K-40	F	1.03E-11	7.98E-07	1.51E-11	1.36E+09	5.41E-10	8.26E-01	1.06E+02	1.06E+06	2.66E-01	2.65E-01
Ra-226+D	M	1.16E-08	8.49E-06	2.95E-10	1.36E+09	4.33E-04	9.26E-01	5.45E+00	9.43E+02	2.24E-02	2.23E-02
Ra-228+D	M	5.23E-09	1.23E-05	6.70E-10	1.36E+09	1.21E-01	9.26E-01	7.57E+00	6.59E+03	4.87E-02	4.84E-02
Th-228	S	1.32E-07	5.59E-09	6.40E-11	1.36E+09	3.62E-01	9.80E-01	2.26E+02	7.46E+02	2.90E+02	1.09E+02
Th-230	S	2.85E-08	8.19E-10	7.73E-11	1.36E+09	9.00E-06	9.97E-01	2.07E+01	3.82E+02	2.15E+02	1.80E+01
Th-232	S	4.33E-08	3.42E-10	8.47E-11	1.36E+09	4.93E-11	9.98E-01	1.89E+01	2.51E+02	5.13E+02	1.70E+01
U-233	M	1.16E-08	9.82E-10	5.22E-11	1.36E+09	4.37E-06	9.98E-01	3.07E+01	9.37E+02	1.79E+02	2.55E+01
U-234	M	1.14E-08	2.52E-10	5.11E-11	1.36E+09	2.83E-06	9.98E-01	3.13E+01	9.54E+02	6.97E+02	2.91E+01
U-235	M	1.01E-08	5.19E-07	4.92E-11	1.36E+09	9.85E-10	9.60E-01	3.25E+01	1.08E+03	3.52E-01	3.48E-01
U-235+D	M	1.01E-08	-	5.03E-11	1.36E+09	9.85E-10	9.60E-01	3.18E+01	1.08E+03	-	3.09E+01
U-238+D	M	9.35E-09	1.14E-07	5.62E-11	1.36E+09	1.55E-10	9.79E-01	2.85E+01	1.16E+03	1.57E+00	1.49E+00
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Attachment B-6

USEPA Superfund Radionuclide Preliminary Goals for Superfund — Site-Specific PRGs for Onsite Worker Scenario (website accessed February 27, 2012)

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Site-Specific Onsite Worker Equation Inputs for Soil Variable	Value
Slab size for ACF (area correction factor) m^2	10,000
TR (target cancer risk) unitless	0.000001
t_{ow} (time - outdoor worker) yr	20
ED_{ow} (exposure duration - outdoor worker) yr	20
ET_{ow} (exposure time - outdoor worker) hr/day	8
EF_{ow} (exposure frequency - outdoor worker) day/yr	150
IR_{ow} (soil intake rate - outdoor worker) mg/day	100
IRA_{ow} (inhalation rate - outdoor worker) m^3/day	60
GSF_o (gamma shielding factor - outdoor) unitless	1
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Site-Specific
Onsite Worker PRGs for Soil

Isotope	ICRP Lung Absorption Type	Inhalation Slope Factor *(risk/pCi)*	External Exposure Slope Factor *(risk/yr per pCi/g)*	Adult Soil Ingestion Slope Factor *(risk/pCi)*	Particulate Emission Factor *(m^3/kg)*	Lambda	Area Correction Factor	Ingestion PRG *(pCi/g)*	Inhalation PRG *(pCi/g)*	External Exposure PRG *(pCi/g)*	Total PRG *(pCi/g)*
Cs-137+D	F	1.19E-11	2.54E-06	3.17E-11	1.17E+09	2.31E-02	8.77E-01	1.31E+02	2.05E+06	2.05E-01	2.04E-01
K-40	F	1.03E-11	7.98E-07	1.51E-11	1.17E+09	5.41E-10	8.26E-01	2.21E+02	1.90E+06	5.54E-01	5.52E-01
Ra-226+D	M	1.16E-08	8.49E-06	2.95E-10	1.17E+09	4.33E-04	9.26E-01	1.13E+01	1.70E+03	4.66E-02	4.64E-02
Ra-228+D	M	5.23E-09	1.23E-05	6.70E-10	1.17E+09	1.21E-01	9.26E-01	1.32E+01	9.92E+03	8.49E-02	8.43E-02
Th-228	S	1.32E-07	5.59E-09	6.40E-11	1.17E+09	3.62E-01	9.80E-01	3.78E+02	1.08E+03	4.83E+02	1.77E+02
Th-230	S	2.85E-08	8.19E-10	7.73E-11	1.17E+09	9.00E-06	9.97E-01	4.31E+01	6.87E+02	4.47E+02	3.72E+01
Th-232	S	4.33E-08	3.42E-10	8.47E-11	1.17E+09	4.93E-11	9.98E-01	3.94E+01	4.52E+02	1.07E+03	3.50E+01
U-233	M	1.16E-08	9.82E-10	5.22E-11	1.17E+09	4.37E-06	9.98E-01	6.39E+01	1.69E+03	3.72E+02	5.28E+01
U-234	M	1.14E-08	2.52E-10	5.11E-11	1.17E+09	2.83E-06	9.98E-01	6.52E+01	1.72E+03	1.45E+03	6.02E+01
U-235	M	1.01E-08	5.19E-07	4.92E-11	1.17E+09	9.85E-10	9.60E-01	6.78E+01	1.94E+03	7.33E-01	7.24E-01
U-235+D	M	1.01E-08	-	5.03E-11	1.17E+09	9.85E-10	9.60E-01	6.63E+01	1.94E+03	-	6.41E+01
U-238+D	M	9.35E-09	1.14E-07	5.62E-11	1.17E+09	1.55E-10	9.79E-01	5.93E+01	2.09E+03	3.27E+00	3.09E+00

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Attachment B-7

USEPA Superfund Radionuclide Preliminary Goals for Superfund — Site-Specific PRGs for Adolescent Trespasser Scenario
(website accessed February 27, 2012)

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Site-Specific Adolescent Trespasser Equation Inputs for Soil **Variable**	**Value**
Slab size for ACF (area correction factor) m^2	10,000
TR (target cancer risk) unitless	0.000001
t_{ow} (time - outdoor worker) yr	10
ED_{ow} (exposure duration - outdoor worker) yr	10
ET_{ow} (exposure time - outdoor worker) hr/day	18
EF_{ow} (exposure frequency - outdoor worker) day/yr	90
IR_{ow} (soil intake rate - outdoor worker) mg/day	100
IRA_{ow} (inhalation rate - outdoor worker) m^3/day	20
GSF_o (gamma shielding factor - outdoor) unitless	1
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Site-Specific
Adolescent Trespasser PRGs for Soil

Isotope	**ICRP Lung Absorption Type**	**Inhalation Slope Factor** *(risk/pCi)*	**External Exposure Slope Factor** *(risk/yr per pCi/g)*	**Adult Soil Ingestion Slope Factor** *(risk/pCi)*	**Particulate Emission Factor** *(m^3/kg)*	**Lambda**	**Area Correction Factor**	**Ingestion PRG** *(pCi/g)*	**Inhalation PRG** *(pCi/g)*	**External Exposure PRG** *(pCi/g)*	**Total PRG** *(pCi/g)*
Cs-137+D	F	1.19E-11	2.54E-06	3.17E-11	1.17E+09	2.31E-02	8.77E-01	3.93E+02	8.19E+06	2.72E-01	2.72E-01
K-40	F	1.03E-11	7.98E-07	1.51E-11	1.17E+09	5.41E-10	8.26E-01	7.36E+02	8.45E+06	8.20E-01	8.19E-01
Ra-226+D	M	1.16E-08	8.49E-06	2.95E-10	1.17E+09	4.33E-04	9.26E-01	3.77E+01	7.52E+03	6.89E-02	6.88E-02
Ra-228+D	M	5.23E-09	1.23E-05	6.70E-10	1.17E+09	1.21E-01	9.26E-01	2.85E+01	2.86E+04	8.17E-02	8.15E-02
Th-228	S	1.32E-07	5.59E-09	6.40E-11	1.17E+09	3.62E-01	9.80E-01	6.46E+02	2.45E+03	3.67E+02	2.14E+02
Th-230	S	2.85E-08	8.19E-10	7.73E-11	1.17E+09	9.00E-06	9.97E-01	1.44E+02	3.05E+03	6.62E+02	1.14E+02
Th-232	S	4.33E-08	3.42E-10	8.47E-11	1.17E+09	4.93E-11	9.98E-01	1.31E+02	2.01E+03	1.58E+03	1.14E+02
U-233	M	1.16E-08	9.82E-10	5.22E-11	1.17E+09	4.37E-06	9.98E-01	2.13E+02	7.50E+03	5.52E+02	1.51E+02
U-234	M	1.14E-08	2.52E-10	5.11E-11	1.17E+09	2.83E-06	9.98E-01	2.17E+02	7.63E+03	2.15E+03	1.92E+02
U-235	M	1.01E-08	5.19E-07	4.92E-11	1.17E+09	9.85E-10	9.60E-01	2.26E+02	8.62E+03	1.09E+00	1.08E+00
U-235+D	M	1.01E-08	-	5.03E-11	1.17E+09	9.85E-10	9.60E-01	2.21E+02	8.62E+03	-	2.15E+02
U-238+D	M	9.35E-09	1.14E-07	5.62E-11	1.17E+09	1.55E-10	9.79E-01	1.98E+02	9.31E+03	4.85E+00	4.73E+00
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APPENDIX C

Ecological Risk Assessment

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LIST OF ATTACHMENTS

C.1 INTRODUCTION

The ecological risk assessment (ERA) for the Wetland Area at Dunbarton Bay (NBN) in support of the Steel Creek Integrator Operable Unit (IOU) is presented in this appendix. From this point forward, this area will be referred to as Dunbarton Bay. Although the unit is referred to as the Wetland Area at Dunbarton Bay, only a portion of the investigation area is classified as wetlands. The wetland portion is primarily located within the boundary of the Dunbarton Bay Carolina bay. This wetland is down-gradient of the P-Area Ash Basin (PAB) and the P-007 Outfall, which are subunits of the P-Area Operable Unit (PAOU), where ash disposal activities have presented a pathway for the release of contaminants that may present a risk to human health and the environment.

C.1.1 Background

Similar to each reactor area at the Savannah River Site (SRS), P Area utilized a coal-fired powerhouse to generate steam and electricity with coal ash (coal combustion products) produced as a result of boiler operations. In P Area, this ash was disposed within PAB via a sluice line. In 2010, ash was initially discovered outside the ash basin during the clearing of 35 acres surrounding the basin in preparation for an early removal action. Additional characterization efforts determined that the ash plume extends an additional 45 acres in the south-southwestern portion into Dunbarton Bay, a Carolina bay/wetland. Ash deposits in the wetlands range in depth from 1 to 3 ft. Since the ash is in a wetland area, it was administratively removed from the PAOU and placed in the Steel Creek IOU in 2010.

An ERA has been performed for the PAB (SRNS, 2008). The unit was assessed as a terrestrial ecosystem; no constituents were identified as refined constituents of concern (RCOCs).

C.1.2 Data

There are two datasets associated with the characterization of Dunbarton Bay. The first dataset consisted of ten sample locations (PAB-116, -117, -119, -120, -153, -182, -183, -301, -302, -304) within Dunbarton Bay from the 0- to 1-ft ash/soil interval and two surface water samples (PAB-428, -429). These sample locations are depicted in Chapter 1, Figures 1-8 and 1-9. This data was collected in June 2010 and analyzed by General Engineering Laboratory. The data was verified and validated (V&V) and used in a preliminary risk evaluation that was presented to the Core Team in August 2010 to assist in the determination of the administrative path forward for this area. This dataset has since been upgraded to definitive level data and is presented in the Data Usability Report (DUR) for this project (Appendix A).

A Sampling and Analysis Plan (SAP) was developed in 2011 to address data gaps identified in the original dataset (SRNS, 2011). These data gaps pertained primarily to the ecological risk assessment. More specifically, site specific biological field studies were initiated for metals associated with the ash media. The studies targeted both biotic (i.e., fauna) and abiotic (i.e., ash/soil) media. Although surface water was also intended to be sampled, Dunbarton Bay was dry due to regional draught conditions and no surface water samples were obtained. The Savannah River Ecology Laboratory (SREL) collected and analyzed the ash/soil and biota samples in 2011/2012. The data quality for this dataset is unverified and unvalidated (U&U).

This ERA uses the data that was collected in 2010 for the screening-level evaluation of the ash/soil media and surface water media in Dunbarton Bay. The screening is conducted by comparing the concentrations in ash/soil and surface water to ecological thresholds to determine constituents that warrant further consideration. The data collected and analyzed by SREL in 2011/2012 is used to further assess threats to ecological receptors based on site-specific biological data and biological surveys supplemented by additional ash/soil data. The SREL data is also used along with the 2010 data to conduct site-specific trophic modeling for the raccoon and the great blue heron. The trophic modeling effort is further supplemented with IOU background data. These data are suitable for background comparisons for all of SRS IOUs. Since the data represent various types of wetland environments encountered within the SRS and were collected from IOU subunits where there are no potential impacts from waste units or industrial activities, a more accurate comparison of SRS impacted areas is possible. Finally, earthworm and amphibian studies from a similar site (D-Area Ash Wetlands) are used as additional lines of evidence to form the basis for making a remedial decision at this unit from an ecological risk perspective.

C.1.3 Habitats/Receptors

Dunbarton Bay (the Carolina bay) is a wetland comprised of both cypress and hardwood canopy habitats. The area comprised by the Dunbarton Bay investigation unit is a low gradient area containing disturbed and undisturbed upland habitats that gradually slopes down-gradient into the depositional wetland (Dunbarton Carolina bay). Three habitat types exist within the survey/investigation area, these include: 1) 3.0 hectares (7.5 acres) of disturbed and undisturbed portions of a maturing pine and mixed pine hardwood upland and mesic forest; 2) 0.8 hectares (2.0 acres) of upland early successional vegetation along roadside and utility corridor rights-of-ways; and 3) approximately 12 hectares (30.5 acres) of disturbed (overburden of ash deposition) and undisturbed portions of a maturing mixed bottomland and cypress swamp forests. Upland soils down gradient and associated with the PAB are of the Udorthents, Blanton and Fuquay series; hydric soils delineated in the primary impact areas of Dunbarton Bay are of the Pickney series.

The habitat at Dunbarton Bay likely supports both terrestrial and aquatic/semi-aquatic receptors depending on water availability. The media of concern is primarily ash/soil (sediment) and surface water.

Assessment endpoints are tailored to groups of organisms with similar feeding strategies and/or exposure scenarios. Based on these considerations and the specific conditions at Dunbarton Bay, the following preliminary assessment and measurement endpoints and their representative receptors were selected for Dunbarton Bay:

- Protection of soil-dwelling invertebrate communities to maintain species diversity and nutrient cycling. Soil-dwelling invertebrate communities are selected because the soil invertebrate community is ecologically important, is susceptible to constituents in soil, and is exposed at the waste unit. The soil-dwelling invertebrate community is essential for decomposition of detritus and for energy and nutrient cycling. Soil-dwelling invertebrates are an important component of the diet of insectivorous mammals and birds. Earthworms are chosen as the representative species of soil-dwelling invertebrates at Dunbarton Bay because they are probably the most important of the soil-dwelling invertebrates in promoting soil fertility, they are highly exposed to soil constituents, and toxicity information is readily available. The measurement endpoint is a comparison of the measured constituent concentration in soil to earthworm toxicity benchmarks. This preliminary comparison is expressed as a hazard quotient (HQ) calculation based on the screening of verified and validated data collected in 2010. This endpoint is also assessed by the earthworm toxicity study conducted at a similar site (D-Area Ash Wetlands).

- Protection of herbivorous mammal communities to ensure that exposure of contaminants in forage and soils does not have a negative impact on growth, survival, and reproduction. Herbivorous mammals are ecologically important because they provide a food base for higher trophic-level receptors and they are also susceptible to soil constituents at the waste unit. Oldfield mice are chosen as the representative species of herbivorous mammals because they are exposed to soil constituents by their consumption of plant material at the unit. They also ingest soil during feeding. The measurement endpoint is a comparison of the modeled constituent concentrations in the food chain using the measured concentrations in soil to ecological threshold values applicable to wildlife receptors that are based on measured responses of similar species in laboratory studies. This preliminary comparison is expressed as an HQ calculation based on the screening of verified and validated data collected in 2010.

- Protection of insectivorous mammal communities to ensure that exposure of contaminants in prey, forage, and soils does not have a negative impact on growth or survival. Insectivorous mammals are ecologically important because they help to control the size of the terrestrial invertebrate population that might otherwise damage populations of plant primary producers. They are also susceptible to soil constituents at the waste unit. Short-tailed shrews are chosen as the representative species of the insectivorous mammals because they are highly exposed to constituents by their consumption of large quantities of terrestrial invertebrates. They also ingest soil during feeding, including soil within the bodies of earthworms and other prey. The measurement endpoint is a comparison of the modeled constituent concentrations in the food chain using the measured concentrations in soil to ecological threshold values applicable to wildlife receptors that are based on measured responses of similar species in laboratory studies. This preliminary comparison is expressed as an HQ calculation based on the screening of verified and validated data collected in 2010.

- Protection of omnivorous mammal communities to ensure that exposure of contaminants in prey, forage and abiotic media does not have a negative impact on growth, survival and reproduction. Mammalian omnivores are ecologically important because they consume a variety of small mammals and plants, helping balance the populations of terrestrial invertebrates, rodents, and other small mammals as well as disperse seeds for plant reproduction. They are also susceptible to soil constituents at the waste unit. Raccoons were chosen as the representative receptor because they are exposed to constituents by their consumption of terrestrial invertebrates and small mammals. They also ingest soil during feeding, including soil within the bodies of earthworms and other prey. The measurement endpoint is a comparison of the modeled constituent concentrations in the food chain using the measured concentrations in soil to ecological threshold values applicable to wildlife receptors that are based on measured responses of similar species in laboratory studies. This preliminary comparison is expressed as an HQ calculation based on the screening of verified and validated data collected in 2010. This endpoint is also assessed by the site-specific raccoon trophic model conducted using the data collected in 2010 and the SREL soil/ash and biological data collected in 2011/2012.

- Protection of insectivorous bird communities to ensure that exposure of contaminants in prey, forage, and soils does not have a negative impact on growth, survival, and reproduction. Insectivorous birds are ecologically important because they help to control the size of the terrestrial invertebrate population that might otherwise damage populations of plant primary producers. They are also susceptible to soil constituents at the waste unit. American robins are chosen as the representative species of the insectivorous bird niche because they are highly exposed to constituents by their consumption of terrestrial invertebrates. They also ingest soil during feeding, including soil within the bodies of earthworms and other prey. The measurement endpoint is a comparison of the modeled constituent concentrations in the food chain using the measured concentrations in soil to ecological threshold values applicable to wildlife receptors that are based on measured responses of similar species in laboratory studies. This preliminary comparison is expressed as an HQ calculation based on the screening of verified and validated data collected in 2010.

- Protection of carnivorous bird communities to ensure that exposure of contaminants in prey does not have a negative impact on growth, survival and reproduction. Carnivorous birds are ecologically important because they are top predators that help control the size of the small mammal populations that might otherwise destroy primary plant producers. They are also susceptible to soil constituents at the waste unit. Red-tailed hawks were chosen as the representative receptor because they are common avian predators and they are exposed to constituents by their consumption of small rodents and snakes. The measurement endpoint is a comparison of the modeled constituent concentrations in the food chain using the measured concentrations in soil to ecological threshold values applicable to wildlife receptors that are based on measured responses of similar species in laboratory studies. This preliminary comparison is expressed as an HQ calculation based on the screening of verified and validated data collected in 2010.

- Protection of benthic invertebrate (sediment dwelling organism) communities from toxic effects of contaminants in order to maintain species diversity, biomass, and nutrient cycling (trophic structure). Identification of a specific receptor for this endpoint is not necessary. The benthic invertebrate community is ecologically important, serving as prey items for many other species as well as maintaining nutrient cycling in an aquatic system. Benthic organisms are also susceptible to constituents in sediment and are potentially exposed at Dunbarton Bay. The measurement endpoint is the measured concentration in sediment media compared to sediment toxicity threshold values. This preliminary comparison is expressed as an HQ calculation based on the screening of verified and validated data collected in 2010.

- Protection of aquatic organism communities from the toxic effects of contaminants in abiotic media and food in order to maintain species diversity and to ensure that ingestion of contaminants in fish and aquatic invertebrates does not have a negative impact on growth, survival and reproduction. The aquatic community is ecologically important, serving as prey items for many species. Aquatic organisms are susceptible to constituents in surface water and are potentially exposed to contamination at Dunbarton Bay. The measurement endpoint is the measured concentration in surface water media compared to ambient water quality criteria. This preliminary comparison is expressed as an HQ calculation based on the screening of verified and validated data collected in 2010.

- Protection of aquatic, semi-aquatic and terrestrial organism communities from the toxic effects of contaminants in abiotic media and food in order to maintain species diversity and to ensure that ingestion of contaminants in vertebrate /invertebrates does not have a negative impact on growth, survival and reproduction. The ecological communities associated with Dunbarton Bay are ecologically important, serving as prey items for many species. Organisms within the Bay system are susceptible to constituents in soil and are potentially exposed to contamination at Dunbarton Bay. The measurement endpoints are (1) a comparison of whole body contaminant burdens for various taxon groups in Dunbarton bay to reference bay 100 and to similar study sites in D-Area, and; (2) biological surveys of species composition of Dunbarton bay compared to the reference bay. These endpoints are assessed using the SREL biological surveys and data collected in 2011/2012.

- Protection of avian aquatic predators in order to ensure that exposure to contaminants in aquatic prey and abiotic media does not have a negative impact on growth, survival, and reproduction. Aquatic predators are ecologically important, are susceptible to constituents in surface water and sediment, and are potentially exposed via food chain uptake to contamination migrating from the waste unit. The green heron was chosen as the representative receptor since it would be exposed via ingestion of biotic and abiotic media associated with Dunbarton Bay. The measurement endpoint is a comparison of the modeled constituent concentrations in the food chain using the measured concentrations in sediment/surface water compared to ecological threshold values applicable to wildlife receptors that are based on measured responses of similar species in laboratory studies. This preliminary comparison is expressed as an HQ calculation based on the screening of verified and validated data collected in 2010. This endpoint is also assessed by the site-specific trophic model for the great blue heron conducted using the data collected in 2010 and the SREL soil/ash and biological data collected in 2011/2012.

- Protection of mammalian aquatic predators in order to ensure that exposure to contaminants in aquatic prey and abiotic media does not have a negative impact on growth, survival, and reproduction. Aquatic predators are ecologically important, are susceptible to constituents in surface water and sediment, and are potentially exposed via food chain uptake to contamination migrating at the waste unit. The raccoon was chosen as the representative receptor since it would be exposed via ingestion of biotic and abiotic media associated with Dunbarton Bay. The measurement endpoint is a comparison of the modeled constituent concentrations in the food chain using the measured concentrations in sediment/surface water to ecological threshold values applicable to wildlife receptors that are based on measured responses of similar species in laboratory studies. This preliminary comparison is expressed as an HQ calculation based on the screening of verified and validated data collected in 2010. This endpoint is also assessed by the site-specific trophic model for the raccoon conducted using the data collected in 2010 and the SREL soil/ash and biological data collected in 2011/2012.

The preliminary conceptual site model (CSM) for the Dunbarton Bay is provided in Chapter 1. Data used in this evaluation are provided in Appendix A of this document.

C.1.4 Sources of Literature-Based Toxicity Values

Ecological thresholds (ETs) are risk-based tools developed by the Savannah River Site (SRS) that can be used to evaluate potentially contaminated sites. ETs are used to conduct the screening-level ecological effects evaluation presented in Section 2.1. ETs are chemical concentrations that correspond to a fixed level of risk, i.e., a HQ equal to one. Derivation of the ETs is simply a rearrangement of the standard risk calculation. However, instead of using the exposure point concentration (EPC) to solve for a risk number, the risk number is set to the threshold value of one and the concentration term is solved for. ETs are based on pathways and receptors for which generally accepted methods, models, and assumptions have been developed (WSRC, 2006a). The *Ecological Thresholds for Soil* (WSRC, 2004a) technical justification document identifies the ETs for soil invertebrates, mammals and birds used in this evaluation. Additionally, the *Ecological Thresholds for Sediment* (WSRC, 2004b) and the *Ecological Thresholds for Surface Water* (WSRC 2004c) identify the ETs for benthic invertebrates, aquatic organisms, mammals and birds used in the evaluation of aquatic/semi-aquatic systems.

C.2 ECOLOGICAL RISK ASSESSMENT PROCESS

This ERA for Dunbarton Bay consists of steps designed to provide a scientifically based and defensible assessment of exposure and hazard to ecological resources that will support a risk management decision regarding site remediation. The ERA for Dunbarton Bay includes a screening-level ecological effects evaluation (Section C.2.1) based on a comparison of constituent concentrations in ash/soil and surface water media to relevant ecological screening thresholds. The ERA also includes and evaluation of biological data (Section 2.2) to assess the potential threat of contaminants to ecological receptors within the Dumbarton Bay system.

C.2.1 Screening-level Ecological Effects Evaluation

The purpose of the screening-level ecological effects evaluation for Dunbarton Bay is to identify constituents that may pose unacceptable risk to ecological receptors, to focus subsequent investigations, and to identify gaps in the available data needed to perform a more comprehensive ERA. The screening-level evaluation assists in making a risk management decision regarding whether remediation from an ecological perspective is warranted, or if the site should proceed to further ecological evaluations for remedy development.

The data used in this screening-level evaluation is the definitive level data that was collected in June 2010 and analyzed by General Engineering Laboratory. The dataset consists of ten sample locations (PAB-116, -117, -119, -120, -153, -182, -183, -301, -302, -304) within Dunbarton Bay from the 0-1 ft ash/soil interval and two surface water samples (PAB-428, -429). These sample locations are depicted in Chapter 1, Figures 1-8 and 1-9.

Since maximum media concentrations are used in this step of the process, the assumption is made that ecological receptors are exposed to the highest (i.e., worst) concentration of a given constituent present at the unit. The combination of maximum media concentrations and conservative threshold values provide confidence that the constituents of potential concern (COPCs) resulting from the screenings are indeed protective.

C.2.1.1 ESV Screening- Nonradiological Constituents

The ecological effects evaluation identifies the potential for adverse ecological effects based on conservative assumptions. The most conservative value (i.e., lowest concentration) between the *Ecological Screening Values* (ESVs) protocol (WSRC, 2006a) and the no observable adverse effects level (NOAEL)-based ET (WSRC, 2004a; WSRC, 2004b; WSRC, 2004c) is used to conduct the screening-level assessment. For the evaluation of surface water media, the April 2008 SCDHEC Water Quality Standards (chronic values) are also considered. The screening-level evaluation process is outlined below:

Ash media evaluated as soil (terrestrial receptors) and as sediment (aquatic/semi-aquatic receptors):

- Compare the unit maximum concentration to the ESV concentration for the 0 - 1 interval.

- Compare the unit maximum concentration of the naturally-occurring (non-anthropogenic) constituents to 2X the average SRS background concentration (WSRC 2006b; Appendix B-1).
- Constituents exceeding the ESV and background screen are carried forward to Step C.2.1.2.

Surface water media (aquatic receptors):

- Compare the unit maximum concentration to the ESV concentration.
- Constituents exceeding the ESV screen are carried forward to Step C.2.1.2.

C.2.1.2 Screening Level Risk (Hazard) Calculation- Nonradiological Constituents

This evaluation uses the ETs that are described in Section C.1. Because of the conservative assumptions used during the initial risk (i.e., ESV) screen, some of the constituents identified for further evaluation might pose acceptable levels of risk to ecological receptors. The method used to further refine ecological COPCs based on food-chain modeling and calculation of screening-level HQs by comparing the maximum and average concentrations to ETs (NOAEL- or lowest observable adverse effects level [LOAEL]-based ETs) is illustrated in the equation below:

HQ = [maximum and average concentrations] / [NOAEL-based ET and LOAEL-based ET)

Constituents with an HQ >1 are further discussed in Step C.2.1.4.

C.2.1.3 Radiological Screening

The radionuclide benchmark comparison for ecological screening is based on the International Atomic Energy Agency (IAEA) report, which states that irradiation at chronic dose rates of 0.1 rad/day and 1.0 rad/day or less do not appear likely to cause observable changes in terrestrial and aquatic animal populations, respectively (IAEA 1992). Applying a tenfold safety factor, the screening benchmark for terrestrial receptor populations exposed to soil is set at 0.01 rad/day, and the benchmark for aquatic receptor populations exposed to surface water or sediment is 0.1 rad/day.

The radiological benchmark screening values were developed following USEPA guidance as specified in the Steel Creek IOU Work Plan (WSRC 2000a) for the sediment and surface water media and other IOU reports (WSRC 2000b, WSRC 2001a) for soil media. All radiological benchmarks for soil, sediment and surface water media are provided in the Steel Creek IOU Periodic Report (WSRC 2004d). The screening level evaluation process is outlined below:

Ash media evaluated as soil (terrestrial receptors) and as sediment (aquatic/semi-aquatic receptors)

- Compare the unit maximum activity to the ecological radiological screening benchmark activity for the 0 - 1 interval.
- Compare the unit maximum activity of the naturally-occurring (non-anthropogenic) constituents to 2X the average SRS background concentration (WSRC 2006b; Appendix B-1).
- Constituents exceeding the ecological benchmark and background screen are further discussed in Step C.2.1.4.

Surface water media (aquatic receptors):

- Compare the unit maximum activity to the ecological radiological screening benchmark activity.
- Constituents exceeding the ecological benchmark screen are further discussed in Step C.2.1.4.

C.2.1.4 Refinement of Constituents of Potential Concern

C.2.1.4.1 Screening Results

Results of the ESV screening (Step C.2.1.1), screening-level risk calculations (Step C.2.1.2), and radiological constituent screening (Step C.2.1.3) for Dunbarton Bay are provided below:

Table C-1 identifies the following constituents as ecological COPCs based on ESV screening in the 0- to 1-ft ash interval that is evaluated as a terrestrial soil media: arsenic, barium, beryllium, copper, iron, lead, manganese, selenium, thallium and zinc. Table C-2 shows both the NOAEL-based HQ and LOAEL-based HQ calculations (as applicable) using the maximum detected concentration for the six standard terrestrial receptors (earthworm, old field mouse, short-tailed shrew, raccoon, American robin, red-tailed hawk). HQs >1 are indicated for arsenic (mouse, shrew, raccoon), barium (shrew), copper (earthworm), lead (robin), selenium (shrew, raccoon, robin), thallium (mouse, shrew, raccoon, robin), and zinc (robin). Table C-3 shows the HQs based on an average calculation; LOAEL-based HQs are >1 for selenium (shrew, robin), and thallium (shrew, raccoon).

Table C-4 identifies the following constituents as ecological COPCs based on ESV screening in the 0- to 1-ft ash interval that is evaluated as an aquatic sediment media: arsenic, barium, copper, selenium, and thallium. Table C-5 shows both the NOAEL and LOAEL-based HQ calculations (as applicable) using the maximum detected concentration for the three standard aquatic receptors (benthic-dwelling organisms, raccoon, heron). HQs >1 are indicated for arsenic (benthic organisms, raccoon), barium (benthic organisms), copper (benthic organisms), selenium (raccoon), and thallium (raccoon, heron). Table C-6 shows the HQs based on an average calculation; LOAEL-based HQs are >1 for arsenic (benthic-dwelling organisms), barium (benthic-dwelling organisms), selenium (raccoon), and thallium (raccoon).

Table C-7 identifies the following constituents as ecological COPCs based on ESV screening in the surface water media for aquatic/semi-aquatic receptors: aluminum, arsenic, barium, copper, iron, manganese, and vanadium. Table C-8 shows both the NOAEL and LOAEL-based HQ calculations (as applicable) using the maximum detected concentrations for the three standard aquatic receptors (aquatic organisms, raccoon, heron). HQs >1 are indicated for aluminum (aquatic organisms, raccoon), arsenic (raccoon), barium (aquatic organisms), copper (aquatic organisms), iron (aquatic organisms), manganese (aquatic organisms) and vanadium (aquatic organisms). HQs based on an average concentration were not calculated because there are only two analytical results for the surface water media.

The results of the radiological benchmark screening exercise are presented in Table C-9 (ash media evaluated for terrestrial receptors), Table C-10 (ash media evaluated for aquatic/semi-aquatic receptors), and Table C-11 (surface water media evaluated for aquatic/semi-aquatic receptors). No constituents exceeded the radiological benchmark screening values for either the ash or surface water media for any receptors.

C.2.1.4.2 Additional Consideration: Toxicity Data Uncertainty

There is uncertainty associated with ESVs and ETs used in the screening-level evaluation because the toxicity data are not unit-specific. ESVs from the *Ecological Screening Values (ESVs)* protocol (WSRC, 2006a) and terrestrial toxicity values from *Toxicological Benchmarks for Wildlife: 1996 Revision* (Sample et al. 1996) are primarily used in this assessment. Limitations in toxicity values from these sources are common to most other toxicity data sources. These limitations include variations in physiological or biochemical factors that may exist among species, behavioral and ecological parameters that may make species' sensitivity to a contaminant different from that of the test organism, and limited information on long-term effects on natural populations. ESVs and NOAEL-based ETs represent the lower of the available benchmarks to minimize this uncertainty. The resulting thresholds are very conservative and, in some instances, may dramatically overestimate the toxic potential of constituents at the unit. In addition, most laboratory studies use highly bioavailable forms of chemicals during toxicity-related derivations. Since most chemicals in nature are bound or associated with inorganic matrices or organics, many are not as bioavailable as the forms used in the laboratory studies. The combination of using maximum concentrations as intakes and conservative ESVs/ETs provides confidence that the constituents of potential concern (COPCs) resulting from the screenings are protective.

C.2.1.4.3 Additional Consideration: Receptor Uncertainty

In addition, there is uncertainty in the groups of organisms potentially utilizing the Dunbarton Bay. This may be minimized by conducting unit-specific ecological characterizations and using data from field surveys for TES species evaluations. Nevertheless, the receptor species listed as potentially present at the unit are a limited subset of the species that may use the area to some extent for at least a portion of the year. The species evaluated in the screening level ERA are considered to provide a conservative representation of the range of exposures that may be experienced by other species that were not specifically evaluated.

C.2.1.4.4 Additional Consideration: Known Ecological Effects in a Similar Ecosystem

Many formal biological studies have been conducted in the vicinity of the 488-D Ash Basin in D Area. The studies document that adverse effects have occurred in the areas of the active settling basins. The effects observed within the coal-ash affected environment include physiological malformations in salamanders and tadpoles, decreased swimming performance in tadpoles, increased body burdens of metals in various species, increased metabolic rates for several species, endocrine/hormonal effects in amphibians, and vegetative stress and death in plant communities. A critical review of these studies is provided in the *RCRA Facility Investigation/Remedial Investigation Work Plan Addendum for the D-Area Expanded Operable Unit* (WSRC, 2001b).

The D Area Wetland received ash-sluice water from the 488-D Ash Basin. Historical aerial photographs, as well as surface water and sediment sampling results obtained during the RFI/RI characterization efforts, indicate a significant ash plume in the D-Area Wetland. Results of the characterization efforts indicate elevated concentrations of ash-related metals in the surface water and sediment media.

The *Ecological Sampling and Analysis Plan for the D-Area Wetlands Operable Unit* (WSRC, 2002) was published in November 2002. The SAP provides guidance for collecting and analyzing environmental samples of the D-Area Wetlands Operable Unit. The SAP was developed to further reduce ERA process uncertainty through actual field sampling. The plan includes population/community evaluations, bioaccumulation and field tissue surveys, and toxicity testing. Trace metals (e.g., arsenic, mercury, selenium) were identified as the constituents of potential concern.

SREL has been the primary point of contact for these studies and have conducted extensive research on coal combustion wastes (CCW) in the D-Area Ash Plume Wetland (DAPW) over the last decade. The similarity of the environmental conditions (i.e., ash in a wetland habitat) between the DAPW and the situation at Dunbarton Bay is unique. Therefore, it is very likely that many of the studies that have been conducted in the DAPW to support an ERA could also be applied to Dunbarton Bay.

C.2.1.4.5 Lines-of Evidence Evaluation

Typically a recommendation of whether or not a COPC should be carried forward for further remedial evaluation is based on a very thorough analysis of each constituent. The evaluation includes a weight-of-evidence approach that considers nature and extent of contamination, consistency with history of use, presence in background, analytical data quality, and uncertainties associated with toxicity data. However, given the preponderance of SREL research information on the D-Area Ash Plume Wetland and its similarity to Dunbarton Bay, a thorough analysis of each constituent has not been performed at this time and all trace metals are identified as ecological COPCs for further evaluation. No radiological constituents are identified as ecological COPCs since the data screening did not identify any threshold exceedences.

C.2.1.5 Screening-level Ecological Effects Evaluation Conclusion

The following three possible decisions can be made upon completion of the screening level ecological evaluation:

- There are adequate data to conclude that ecological risks are negligible and, therefore, there is no need for remediation on the basis of ecological risk.
- The information indicates a potential for adverse ecological effects, and a more thorough assessment is not warranted.
- The information is not adequate to make a decision at this point, and the ecological risk assessment process will continue to address data gaps.

The screening level ecological effects evaluation for Dunbarton Bay indicates that more information is needed in order to more thoroughly assess the risk potential to ecological receptors. Of primary interest are the trace metals that are naturally occurring in coal and may be concentrated in coal ash because they are not lost during combustion.

C.2.2 Site-Specific Biological Sampling at Dunbarton Bay

The overall objective of the supplemental characterization effort is to obtain additional data to assess the need for remedial actions within the Dunbarton Bay ecosystem. Unit-specific biological data collected for Dunbarton Bay greatly reduces the uncertainties associated with relying strictly on literature-based toxicity values and exposure assumptions. The *Sampling and Analysis Plan for the Wetland Area at Dunbarton Bay (NBN) in Support of the Steel Creek Integrator Operable Unit (U)* (SRNS 2011) describes the project data quality objectives, sampling design and rationale, analytical plan, and field implementation relative to this effort. The SAP targets ash (soil and sediment), surface water, and biota media.

By obtaining biological tissue data, the nature of the contamination within representative biota/taxa can be assessed. Biota samples are taken within the study area. Background samples are also taken in another appropriate Carolina bay system (Bay 100). This data can also be directly applied to the SRS-specific trophic modeling effort to assess threats to trophically linked organisms as well as the organisms being sampled. The data will also be used to infer population level effects based on appropriate endpoints such as reduced fecundity or survivability. Much of the information relating amphibian endpoints will be evaluated based on topically related research conducted by SREL on the effects of coal combustion products associated with ash basins and depositional areas in D Area. The TES species survey will identify species potentially present in the Dunbarton Bay system. This information will be used to assess critical habitat or species within the system that may warrant special consideration. In general, the biological data and additional information will be used to determine if contaminants present within the Dunbarton Bay system pose unacceptable risk to representative populations inhabiting or utilizing the Dunbarton Bay system or to special species of concern.

C.2.2.1 TES Survey Results

In 2012, a *Habitat Assessment and Threatened, Endangered and Sensitive (TES) Survey for Dunbarton Bay* was performed by the United States Department of Agriculture Forest Service-Savannah River (USDA FS-Savannah River). This survey assesses potential threats or critical habitats for species of conservation concern. The report documents the findings of the field surveys and literature reviews to determine the actual or potential occurrence of any proposed, endangered, threatened, and sensitive (PETS) species in the Dunbarton Bay area. The following summary level information is taken directly from the Summary and Conclusion portion of the document; it is provided in its entirety as Attachment C-1. Details regarding the survey area description, PETS species considered for the survey, survey methods, flora and fauna observations, and field survey results can be found in the attachment.

In support of the characterization of the P-Area Ash Basin / Dunbarton Bay/ P-Area Ash Plume Wetland (PAB/DB/PAPW) project area, the USDA FS-SR was tasked with conducting a habitat assessment and PETS species survey. Determination of presence or likelihood of presence of PETS in the PAB/DB/PAPW survey area was made based on historical records, conversations with subject matter experts, literature searches of life history and habitat requirements, site visits and contracted plant surveys, and best professional judgment. Natural resource specialists (biologists, ecologists, and/or botanists) within the USDA FS-SR visited or had surveys conducted within the PAB/DB/PAPW survey area. Where information was lacking or absent, the best scientific and commercial data was utilized. The report documents the findings of field surveys and literature reviews and determined the actual or potential occurrence of any PETS species in the impacted project areas. Results from botanical and wildlife surveys did not identify any critical habitat nor located any PETS species within the project area.

Based upon the above reviews, it was determined that the habitats in the vicinity of the PAB/DB/PAPW survey are generally not suitable for most SRS listed plant and animal PETS species. Compartment 74 lies within the Supplemental Red Cockaded Woodpecker Habitat Management Area and thus is not managed for priority nesting habitat for the red cockaded woodpecker. This means the red cockaded woodpecker is likely absent in the survey area and not expected to occur here in the foreseeable future. Currently, the only potential red cockaded woodpecker nesting habitat is in the upland habitat above the right of way. A portion of this area (approximately 0.6 ha (1acre) is in maturing loblolly pine stand which is currently marked for an intermediate thinning harvest. This stand will be regenerated (clearcut) at 50 years of age and therefore will be unsuitable for any red cockaded woodpecker nesting habitat. Suitable riverine habitat for the short nosed sturgeon is not available and other aquatic species such as the American sand burrowing mayfly are also highly unlikely. Some species, such as the bald eagle and American alligator may move across or briefly through the area as transients but no habitat conditions exist in the project survey area to support these species. There is no suitable sandhill habitat for the gopher tortoise or wetland habitat for the state (South Carolina) endangered gopher frog. There is no suitable aquatic foraging or nesting habitat for the wood stork. There are three known coneflower populations on the SRS, however, none occur in the PAB/DB/PAPW project area and therefore would not be a concern. The smooth coneflower is sometimes found in open right of way habitats that have suitable soils, however, the soils are primarily hydric within the utility and road right of way survey area making it unlikely for the establishment of this species.

A single pondberry population exists on the SRS along the margin of a Carolina bay located well away from the PAB/DB/PAPW project area and therefore would not be a concern. With the possible exception of pondberry habitat most commonly associated with wetland depressions with open canopies, there is no critical habitat designated for PETS plant species within the PAB/DB/PAPW assessment area. The Florida bladderwort, a sensitive plant species reported in the Dunbarton Bay 20 years ago was not relocated in this survey likely due to the lack of open water and closed canopy habitat conditions. USDA-FS SR bird counts of the survey recorded species, one of which is considered species of conservation concern by the South Carolina Department of Natural Resources (SCDNR).

As part of the habitat characterization, game and non-game wildlife species that were heard, seen, captured or evidence observed of wildlife utilizing the project area were recorded. Evidence of big game such as white-tailed deer, feral hogs, and wild turkey were observed in the survey area. Based on SREL's survey data, seventeen species of herpetofuana and two mammal species were captured but did not include any federally or state listed PETS species. It is beyond the scope of this report to ascertain whether there are demonstrable or probable impacts to any known or unknown flora and fauna PETS species associated with the PAPW as a result of the coal ash deposition from the PAB.

C.2.2.2 Savannah River Ecology Laboratory Studies

The SREL collected and analyzed the ash/soil and biota samples in 2011/2012 in support of this ERA. The following lines-of-evidence were pursued in the study:

- Determination of the amphibian species utilizing the Dunbarton Bay (Bay 96) and a reference site (Bay 100)

- Quantification of trace element accumulation for select species (including reptiles, small mammals, ground beetles, etc.)
- Comparison of food web trace elements at two sites (P-Area vs. D-Area)
- Assessment of Dunbarton Bay suitability as amphibian breeding site

The *P-Area Wetland Studies Soils and Biota* is provided in its entirety as Attachment C-2. Details regarding the background, objectives, methods, and results can be found in the attachment. The following summary level information is taken directly from the Discussion and Conclusions portions of the report. Note that the citations provided here are formally referenced in the report.

Discussion: Determining whether low-level chronic exposure to contaminants affects population viability is a major challenge in ecotoxicology. Amphibians are ideally suited for examining contaminant effects because they are important components of aquatic and terrestrial communities, and often are sensitive to environmental contaminants. In particular, their permeable skin and susceptibility in both aquatic and terrestrial habitats puts them at high risk. Amphibians have been the subjects of numerous ecotoxicology studies (reviewed in Linder et al. 2003 and Sparling et al. 2000). Exposure to metals found in fly ash can have a range of effects including decreased survivorship of frog (Baud & Beck 2005; Rowe et al. 2001) and salamander (Horne & Dunson 1995; Roe et al. 2006) larvae, increased time to metamorphosis (James et al. 2005; Roe et al. 2006), and decreased size at metamorphosis (Peterson et al. 2009). An effect on body size at metamorphosis is critical because it affects adult fitness traits such as age at first reproduction, survival, and fecundity (Semlitsch et al. 1988; Scott 1994). Similarly, a contaminant-induced delay in metamorphosis may result in catastrophic mortality in a drying pond (Semlitsch et al. 1996). Ultimately, assessment of population-level effects requires knowledge of biological effects beyond measurements of contaminant body burdens.

Elevated levels of five trace elements (arsenic, strontium, iron, cobalt, and thallium) were observed in the Bay 96 ash-impacted soils compared to concentrations in the two cores taken within the Bay 100 wetland. Surface soil concentrations of five additional elements (vanadium, copper, nickel, zinc, chromium) were elevated at the Bay 96 drift fence locations — these differences between the two sites may be related to textural differences between the wetland soils at Bay 96 fences and the bay rim/upland soils at Bay 100. Bay 100 had elevated aluminum and lead levels compared to Bay 96 soils. Biota at Bay 96 had elevated tissue concentrations of arsenic, selenium and strontium compared to biota from the reference site (Bay 100); mercury and lead were higher in tissue at Bay 100. Elevated lead at Bay 100 may possibly be due to pre-SRS waterfowl hunting, as lead shot accumulates and settles slowly in wetland sediments (Mudge 1984). No population-level effects related to these elevated body burdens were observed, although chronic sub-lethal exposure studies were not conducted.

All prior SREL research on the ecological effects of CCW has been conducted within the D-Area system, and conclusions may be limited to that system. Studies on amphibians exposed to CCW in the D-Area receiving ponds and primary/secondary ash settling basins revealed that numerous species accumulate high concentrations of trace elements, which elicit several adverse responses (Rowe et al. 1996, 1998; Hopkins et al. 1997, 1999, 2000, 2006; Snodgrass et al. 2004). For example, southern toads inhabiting the D-Area primary settling basin bioaccumulated metals (Hopkins et al. 1998), had increased stress hormones (Hopkins et al. 1997, 1999) and experienced reduced larval recruitment (Rowe et al. 2001). Narrow-mouth toads (*Gastrophryne carolinensis*) from the primary basin accumulated traced elements and transferred significant quantities of selenium and strontium to their eggs, had reduced hatching success, and increased larval developmental abnormalities, abnormal swimming behavior, and overall viability (Hopkins et al. 2006). Mole salamander larvae reared in mesocosms containing ash sediments from the D-Area receiving basins also accumulated trace elements and had reduced larval growth rate and survival to metamorphosis (Roe et al. 2006). These studies suggest that recently disposed CCW (i.e., in open receiving and settling basins) has sub-lethal effects on amphibians that may affect populations.

Recent D-Area research (Metts et al., in press) found that southern toads inhabiting the D-Area also maternally transferred trace elements to their eggs. In addition, these females produced smaller clutches of eggs and experienced decreased hatching success. In fact, overall reproductive success of the DAB and DAPW females was reduced 39% and 28%, respectively, compared to reference females. Furthermore, larvae from ash basin and ash plume females had a 25% decrease in survival to metamorphosis compared to reference females. Moreover, larvae reared in CCW sediments had extended larval period, were smaller at metamorphosis, and had reduced performance compared to those reared in reference sediments. These data suggest that some CCW-contaminated habitats may be an environmental "sink" to some amphibian species.

At Bay 96, tissue and sediment concentrations of COPCs were generally lower than levels in the DAPW, and much lower than the D-Area settling basins. For elements that showed a significant correlation between soil and tissue concentrations, Bay 96 levels were lower than DAPW and DAB levels. Whether the low-level body burdens observed at Bay 96 translate to significant individual- or population-level effects is unknown.

In addition to contaminants, numerous factors influence amphibian diversity, population size, and demography. The amount of time a wetland holds water (i.e., hydroperiod) is a primary determinant of juvenile recruitment, species diversity, and species composition (Pechmann et al. 1989, Snodgrass et al. 2000). Although fewer captures of amphibians occurred at Bay 96 compared to Bay 100 for most species, the most parsimonious explanation for the reduced numbers is the hydroperiod (observed and long-term average) of the sites. During the sampling Bay 96 did not hold water; Bay 100 had pockets of water for two months, which enabled successful recruitment by mole salamanders and may have attracted breeding southern toads. The elevated tissue mercury in biota at Bay 100 also suggests a longer hydroperiod. Spadefoot toads, a short hydroperiod specialist, were more numerous at Bay 96. In addition, the drift fences at each site may have sampled different types of animals: relatively sparsely distributed residents living on the ash-impacted area at Bay 96 vs. breeding immigrants attracted to water at Bay 100.

Conclusion: Long-term stewardship of DOE lands and surface waters requires landscape-level management that maintains a healthy ecosystem and minimizes ecological risks from legacy contaminants such as CCW. Decisions concerning acceptable clean-up and closure of CCW sites require monitoring the diversity and success of the biota inhabiting the area, preferably by direct measurement of biological effects. This study documented COPC levels in soils and biota, but did not directly assess biological effects.

Past SREL research in the D-Area system has assessed the effects of CCW on vertebrates. Previous studies have documented contaminant bioaccumulation, with accompanying individual-level effects (e.g., altered behavior, increased deformities, reduced growth) and population-level effects (e.g., reduced recruitment and offspring viability) in some species, with the most deleterious effects being associated with the highest level of contaminants (i.e., in active ash settling basins). In general, biological effects in the DAPW remain elevated compared to reference sites but are below levels observed for the primary and secondary ash basins. Similarly, trace element concentrations in surface sediments in the DAPW have attenuated compared to the DAB sediments. Both the forest plant community and the amphibian community have a species composition that appears to be "normal" for the type and age of the habitat. The trace element concentrations at Bay 96 are lower than at the DAPW, and it also appears to have a typical amphibian community compared to the nearby reference site.

Site remediation decisions require an assessment of the potential ecosystem-level risk of trace element contaminants to organisms, including: 1) a species list (biological survey) for the habitat of interest for comparison to reference sites, 2) species-specific estimates of trace element concentrations (body burdens), and 3) the measurement of endpoints that reflect the individual and population-level consequences of elevated trace element body burdens (population effects). In this study, biological surveys were conducted at Bay 96, Bay 100, and select D-Area sites for comparison, and determined trace element tissue concentrations in a variety of organisms. Given the time and funding constraints, extensive population demography studies or experimental assessment of chronic sub-lethal effects at the observed trace metal concentrations in Bay 96 were not conducted. Consequently, prior experiments at CCW levels in the D-Area system to speculate about potential CCW impacts on biota in P-Area are relied on.

In general, the biota that were examined at Bay 96 had elevated arsenic, selenium and strontium tissue concentrations compared to animals from Bay 100. Despite these differences, concentrations in Bay 96 fauna were relatively low (e.g., arsenic, 3-6 mg/kg; selenium, 0.8-3 mg/kg) compared to those captured at the D-Area Primary Ash Settling Basin (arsenic, 3-7 mg/kg; selenium, 15-46 mg/kg) and D-Area Ash Plume Wetland (arsenic 1.6-3.4 mg/kg; selenium, 6-22 mg/kg). Tissue concentrations were highly correlated with soil concentrations for arsenic, selenium and strontium, and soil concentrations of these COPC were elevated in the D-Area system compared to P-Area (Bay 96).

For amphibians, both the contaminated site (Bay 96) and the reference site (Bay 100) were similar in species richness and composition. Greater numbers of captures occurred at Bay 100, it is thought that this was primarily due to 1) the presence of water for portions of the sample period at Bay 100 but not at Bay 96, and 2) a difference in configuration of the sampling fences that were likely sampling animals during their breeding migration at Bay 100 but only resident animals at Bay 96. Thus, any population-level differences between the two sites were more likely due to between-site hydroperiod differences rather than any direct effects of elevated COPC at Bay 96.

C.2.2.3 Site-Specific Trophic-Level Modeling

Trophic-level modeling was conducted using the site-specific data that was collected and analyzed by SREL in 2010/2011. This effort addressed the uncertainty associated with relying strictly on literature-based toxicity values and exposure assumptions. Results of the modeling effort, *Ecological Effects of Contaminants in the P-Area Wetlands,* is provided in its entirety as Attachment C-3. The following excerpt is taken directly from the Executive Summary portion of the report.

The objective of this study was to evaluate the risks posed by trace metals in coal ash to higher trophic level organisms that may feed in impacted portions of Dunbarton Bay. This was accomplished by using contaminant exposure models that assess the effects on ecological receptors of trace metals in food, water, and ingested soil. Models for the raccoon *Procyon lotor* and great blue heron *Ardea herodias*, previously developed for use in the SRS Integrator Operable Unit (IOU) assessment program, were modified to reflect the food sources occurring in wetlands. Input data for the models included trace metal concentrations in biota, sediment, and water collected during recent surveys of the Dunbarton Bay wetlands.

Arsenic concentrations in sediments and the tissues of potential forage organisms consumed by raccoons and blue herons (i.e., amphibians, reptiles, invertebrates, and small mammals) were higher in areas affected by coal ash deposition than in uncontaminated reference areas. Other metals including selenium and strontium were also elevated in at least some forage organisms collected from the areas of ash deposition. However, no metals were present at concentrations high enough to produce exposure doses that posed potential ecological risks to raccoons or blue herons that feed in the Dunbarton Bay wetlands. The only metal that exceeded toxicity reference values was aluminum, which exceeded the lowest observed adverse effect level (LOAEL) for the raccoon at both impacted and uncontaminated reference sites as a result of the incidental consumption of soil. As noted in previous reports, aluminum exceedances in SRS soils are common, even in reference areas, and related to naturally high aluminum levels in soils rather than to SRS industrial operations.

Overall, results of the modeling effort show that contaminants associated with the abiotic media or biotic components of Dunbarton Bay do not represent a contaminant risk to predatory birds or omnivorous mammals which likely represent high exposure receptors for the system. Aluminum, the only constituent that resulted in a HQ greater than 1 had a higher concentration in the reference bay (Bay 100) than was observed at Dunbarton Bay. As such, the results of the modeling effort show no evidence that the contaminants present within the Dunbarton system pose an ecological threat.

C.2.3 Additional Risk Information and Uncertainty Evaluation

This purpose of this section is to provide additional information for interpreting the risk results. It addresses some of the exposure effects information presented to this point and summarizes associated uncertainties. In general, constituent screening based on literature-based toxicity values inherently rests on many assumptions. Several aspects of the uncertainties associated with the use of literature-based ecological thresholds are discussed in the following sections. The constituent screening is supplemented by site-specific biological data that was tailored to address key uncertainties associated with constituent screening. Other lines of evidence, including the results of other studies conducted in ash deposited wetland systems, are used as further lines of evidence to assess the health of the Dunbarton Bay system and potential contaminant threats.

C.2.3.1 Re-Evaluation of Preliminary Screening Level Assessment

A thorough analysis of each constituent was not performed in the screening-level effects evaluation (Section 2.1) and all trace metals were identified as ecological COPCs for further evaluation. The additional uncertainty discussion provided in this section is in accordance with the *Constituents of Concern Refinement Process Protocol* (WSRC 2006a). SRS soil background concentrations were obtained from Appendix B-2 of the *Background Soils Statistical Summary Report* (WSRC 2006b).

Average unit concentrations are typically given more significance than maximum concentrations in ecological risk assessments since the ecological receptors under consideration are not sedentary and their exposure will be over a larger area than that encountered at a single sampling location. The exception to the assumption of non-sedentary behavior are soil invertebrates and benthic dwelling organisms. However, this is offset by the fact that the soil invertebrate and benthic organism endpoints are established at the community-level, and effects caused by a maximum concentration at a single location would not cause community-level impacts. Therefore, the following lines-of-evidence discussion is only presented for the constituents that have a HQ based on an average concentration equal to or exceeding one (i.e., $HQ_{avg} > 1$).

In general, NOAEL-based HQs are considered screening benchmarks that are not used to make remedial decisions at a waste unit unless threatened, endangered or sensitive (TES) species are present since these species are protected at the individual level. For the evaluation of wildlife receptors, the preferred toxicity test endpoint is the lowest appropriate chronic LOAEL for non lethal or reproductive effects. It follows that LOAEL-based HQs are appropriate for evaluating risk to non-threatened and endangered receptor populations (Suter et al. 1994). The risk information presented in Section C.2.1 shows the range of HQs based on both the NOAEL and LOAEL toxicity values. Since no TES species are expected to occur at Dunbarton Bay, only the LOAEL-based HQs were used in the uncertainty evaluation to provide a quantitative measure to assess the potential for adverse ecological impacts at the community level**.**

For the receptors that have a home range greater than the size of the waste unit (i.e., raccoon and hawk), a unit foraging factor (UFF) can be applied to further refine the HQ calculation. The impacted area of Dunbarton Bay is approximately 38 acres (15.2 hectares). The calculated HQ can be adjusted to take into account the size of the unit and the home range of the receptor by multiplying the HQ by the UFF (if the unit area home range is less than one). The UFF information for Dumbarton Bay is provided below.

Unit-Specific Foraging Factor Information

Receptor	Home Range *(ha)*	Dunbarton Bay *(ha)*	Unit Specific Foraging Factor
Shrew	3.90E-01	1.52E+01	3.90E+01
Mouse	1.64E-01	1.52E+01	9.27E+01
Raccoon	5.20E+01	1.51E+01	**2.92E-01**
Robin	4.20E-01	1.52E+01	3.62E+01
Hawk	2.33E+02	1.52E+01	**6.52E-02**
Heron	1.50E+00	1.52E+01	1.01E+01

UFF = smaller of 1 and unit area/home range. Those receptors with home ranges exceeding the size of the waste unit are noted in bold.

Table C-3 (terrestrial receptors, ash evaluated as soil media) shows LOAEL-based HQs > 1 for selenium (shrew HQ = 3.7, robin HQ= 2.4), and thallium (shrew HQ = 13, raccoon HQ = 1.2, [HQ <1 using UFF adjustment]).

Table C-6 (aquatic receptors, ash evaluated as sediment media) shows LOAEL-based HQs > 1 for selenium (raccoon HQ = 1.9, [HQ <1 using UFF adjustment]), and thallium (raccoon HQ = 4.2, [HQ = 1.2 using UFF adjustment). In addition, arsenic (benthic-dwelling organisms) and barium (benthic-dwelling organisms) had HQs = 1.8 and 3.4, respectively.

These constituents are discussed in more detail below.

Arsenic was detected in 10 of 10 samples, with 2 sample results being estimated values. Concentrations ranged from 1.82 mg/kg to 33.6 mg/kg, with an average concentration of 14.8 mg/kg. Maximum concentration in SRS background soils is 22.9 mg/kg and the mean concentration is 2.23 mg/kg. Unit concentrations are greater than SRS background concentrations. Arsenic, naturally present in coal, may be concentrated in coal ash because it is not lost during combustion; thus, it is expected in Dunbarton Bay due to the ash material that has been deposited at this unit.

Barium was detected in 10 of 10 samples, with 0 sample results being estimated values. Concentrations ranged from 10 mg/kg to 144 mg/kg, with an average concentration of 68.2 mg/kg. Maximum concentration in SRS background soils is 252 mg/kg and the mean concentration is 16.5 mg/kg. Unit concentrations are within soil background concentrations at SRS.

Selenium was detected in 10 of 10 samples, with 7 sample results being estimated values. Concentrations ranged from 0.61 mg/kg to 5.44 mg/kg, with an average concentration of 2.57 mg/kg. Maximum concentration in SRS background soils is 12.2 mg/kg and the mean concentration is 1.9 mg/kg. Unit concentrations are within soil background concentrations at SRS.

Thallium was detected in 8 of 10 samples, with 5 sample results being estimated values. Concentrations ranged from nondetect (ND) to 3.67 mg/kg, with an average concentration of 1.67 mg/kg. Maximum concentration in SRS background soils is 8.13 mg/kg and the mean concentration is 1.47 mg/kg. Unit concentrations are within soil background concentrations at SRS.

Conclusion: Barium, selenium and thallium are naturally occurring constituents that are common in SRS soils. The concentrations of these constituents are within the SRS background concentrations and they do not appear to be unit related since they are indistinguishable from background.

The concentration of arsenic is greater than SRS background concentrations. It may be concentrated in coal ash because it is not lost during combustion; thus, it is expected in Dunbarton Bay due to the ash material that has been deposited at this unit. However, arsenic only had a HQ >1 for the sediment dwelling organism receptors. See additional discussion below regarding the appropriateness of using sediment dwelling organisms as legitimate receptors at Dunbarton Bay (given the absence of water).

C.2.3.2 Re-Evaluation of Surface Water Media

Two surface water samples were obtained in the 2010 sampling effort. One of these samples was within Dunbarton Bay, and the second was in a drainage located outside of the bay. The samples were obtained from shallow pools of water less than six inches deep. Although a turbidity measurement is not available, it is very likely that there was a high degree of suspended solids that were present in the sample. The screening level assessment identified metals (aluminum, arsenic, barium, copper, iron, manganese and vanadium) as COPCs based on conservative assumptions (Section 2.1.4).

Surface water sampling at multiple locations within Dunbarton Bay was targeted to address this uncertainty. However, no surface water was present during the 2011 sampling event, and it appears that the presence of surface water within the area is highly variable. Therefore, the surface water media does not represent a prolonged, sustainable source of exposure for aquatic/semi-aquatic wildlife receptors.

C.2.3.3 Re-Evaluation of Sediment Toxicity

The screening level assessment identified a potential toxicity exposure issue for sediment dwelling organisms (arsenic and barium). (Note that the sediment dwelling organism receptor pertains to sediment invertebrates generally as a functional group and not to a particular species or taxonomic group). Although the ash (sediment) samples were collected by SREL for chemical analysis, toxicity testing that would directly address uncertainty in the use of conservative literature-based benchmark values was not performed. However, the following information provides a reasonable justification that this is not a significant data gap.

The screening level assessment uses Effects Range-Low (ER-L) values from *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision* (Jones et al. 1997). The National Oceanic and Atmospheric Administration (NOAA) supported the development of these criteria for sediment media. Chemical concentrations observed (or predicted) by methods associated with biological effects were ranked, and the lower 10^{th} percentile ER-L value (most conservative) and median [Effects Range-Media (ER-M)] concentrations were identified.

It is important to note that although the maximum detected concentration of arsenic, barium and chromium exceeded the most conservative ER-L screening value, none of these constituents exceeded the ER-M value. The ER-L was exceeded for arsenic and barium using the average concentration.

This reference document indicates that NOAA values may be used to help identify sites with the potential to cause adverse biological effects, but these are not standards intended for use in regulatory decisions and that these benchmarks do not represent remediation goals. The sediment benchmarks are to be used as screening values only and must not be used as the sole measure of toxicity.

Given the surface water media does not represent a prolonged, sustainable source of exposure for aquatic/semi-aquatic wildlife receptors, it is probable that traditional benthic-dwelling organisms do not exist within the Dunbarton Bay wetland. The PETS substantiates this to some degree by indicating that suitable habitat for aquatic species such as the American sand burrowing mayfly is highly unlikely and that there is no suitable aquatic foraging habitat for the wood stork. Capture by SREL of seven species of amphibians and six reptile species in the Dunbarton Bay wetland in addition to small mammals, spiders, beetles, and millipedes also indicates that sediment dwelling organism are not as likely to be in Dunbarton Bay. In support of the ongoing research of CCW at D-Area, the Savannah River Technology Center (SRTC) conducted toxicity testing for terrestrial invertebrates. Given the lack of surface water within Dunbarton Bay, it is probable that these are more likely receptors than sediment dwelling organisms. Conclusions excerpted from *Earthworm (Eisenia foetida) Toxicity and Bioaccumulation Studies Conducted on Soils Collected from the D-Area Wetland, July-August 2003* are provided below. The study is presented in its entirety in Attachment C-4.

Earthworm toxicity tests were conducted on soils from six locations at the D-Area Wetland, including two reference locations and four locations that contained coal ash. Contaminant body burdens were measured in the earthworms at the end of the toxicity tests. Arsenic was the contaminant of interest because arsenic concentrations in the soils that contain coal ash were close to Oak Ridge National Laboratory Invertebrates Soil Screening Benchmark value of 60 mg/kg and exceeded the EPA Region 4 Soil Screening Benchmark of 10 mg/kg.

The results of the toxicity tests indicated that exposure to the soils did not cause significant mortality to the earthworms. The body burden analyses for arsenic indicate that all of the worms, including those exposed only to the worm bedding in which the worm were reared, had elevated body burdens of arsenic. Arsenic body burdens were similar in worms exposed to reference soils and soils from the D-Area Wetland that contained the coal ash, which indicates little if any uptake of arsenic from the contaminated soils.

Earthworms exposed to some of the soils that contained coal ash had significantly higher body burdens of several metals, including molybdenum, selenium, antimony and strontium. It is doubtful, however that most of these differences are great enough to be biologically significant. The data suggests that EPA Region 4 benchmarks are probably overly conservative.

A comparison of the analytical results from the coal combustion waste from the D-Area Wetland that were used in the earthworm toxicity tests to the material in WADB is provided below:

	As	Cd	Cu	Hg	Mn	Mo	Pb	Sb	Se	V	Zn
D-Area Toxicity Test Data *(mg/kg)*	41-55	<1	30-42	0.12-0.25	28-306	4-9	9-18	<1	5-10	35-55	18-46
WADB V/V Data *(mg/kg)*	1.82-33.6	ND-0.224	1.49-55.8	0.00792-0.0773	9.15-354	Not analyzed	3.62-13.6	Not analyzed	0.61-5.44	6.39-25.8	2.62-55.0

Arsenic was the primary contaminant of interest for the toxicity tests that were conducted in D-Area. The concentration of arsenic from the D-Area Wetland dataset (55 mg/kg) is much higher that the arsenic concentration in the WADB dataset (33.6 mg/kg). All constituents, with the exception of copper and manganese, are higher in the D-Area Wetland dataset. This is not a significant issue since the maximum detected result for these constituents are within the SRS soil background concentrations (74.3 mg/kg and 463 mg/kg, respectively). Therefore, the results of the D-Area toxicity tests can reasonably be used as an additional line of evidence that indicates that the sediments at WADB are not toxic to invertebrates.

C.2.3.4 Evaluation of Bioavailability

The following information on bioavailabilty associated with coal combustion waste (CCW) is taken directly from the SREL report (Attachment C-2).

Coal-fired facilities have operated on the Savannah River Site (SRS) since the early 1950s. Seven coal plants associated with steam generation were once in use on the SRS, each with its own production history and associated CCW. Variation in CCW contaminant levels likely occurs across sites due to individual coal-plant history, source of the parent coal material, and natural attenuation of contaminants after facility shutdown. For example, at D-Area on the SRS, a contaminant concentration gradient occurs from very recently deposited CCW in the primary settling basin to >35-yr-old CCW deposited in a nearby wetland and floodplain. The D-Area Ash Plume Wetland received CCW through the early 1970s, resulting in a CCW plume that extends over 40 ha of floodplain at depths up to 2.7 m. The DAPW has not received CCW discharge for >35 years and the impacted area (including the wetland) has become revegetated with a mixed floodplain community and a thin organic soil layer has developed. Organic matter in the surface horizon of soil facilitates the release and downward transport of metals to lower horizons, where they may be immobilized. Thus, the bioavailability of metals may be reduced in aged sediments from historic CCW deposits where surface leaching has occurred.

In addition, each bulk surface layer sample was extracted using the standard Toxicity Characteristic Leaching Procedure (TCLP), with the extracts analyzed by ICP-MS as per EPA Method 6020A. TCLP extraction has been commonly used to estimate contaminant migration potential. The TCLP extractable contaminant levels for all ash-impacted soils are well below the regulatory threshold for all of the inorganic contaminants, and show no clear trends of enrichment within the ash deposition zone.

The modeling effort also assesses bioavailability (Attachment C-3). Results of the site-specific modeling effort show that contaminants associated with the abiotic media and biotic components of Dunbarton Bay do not represent a contaminant risk to predatory birds or omnivorous mammals which likely represents a high exposure potential for receptors within the Dunbarton system. Aluminum was the only constituent that resulted in a HQ greater than 1 and was observed at a higher concentration in the reference bay (Bay 100) than was observed at Dunbarton Bay. As such, the results of the modeling effort show no evidence that the contaminants present within the Dunbarton system pose a bioavailability threat to ecological receptors.

C.2.4 ERA Summary

A summary of the important highlights of the ERA for Dunbarton Bay is provided below.

1) Characterization data collected in June 2010 was used in the screening-level effects assessment. The definitive level data is presented in the DUR (Appendix A).

2) For nonradionuclides, the screening level effects evaluation (Section C.2.1) compared maximum detected concentrations to ESVs and 2 times average background. Constituents that exceeded the ESV and background screen were carried forward to a screening level hazard calculation. HQs were calculated using maximum detected concentration and both NOAEL-based and LOAEL-based ETs. Typically, a recommendation of whether or not COPCs should be carried forward for further remedial evaluation is based on a very thorough analysis of each constituent. However, given the preponderance of SREL research information on the D-Area Ash Plume Wetland and its similarity to Dunbarton Bay, a thorough analysis was not performed at this time and all trace metals were identified as ecological COPCs for further evaluation. This is considered a conservative approach because no constituents were eliminated in the process.

   No radiological constituents were identified as ecological COPCs since the data screening did not identify any threshold exceedences.

   The screening level effects evaluation indicated that more information was needed in order to more thoroughly assess the risk potential to ecological receptors. Site specific biological sampling was recommended to address uncertainties in the ERA process. Of primary interest are the trace metals that are naturally occurring in coal and may be concentrated in coal ash because they are not lost during combustion.

3) A SAP was developed in 2011 to identified address data gaps in the ERA. The studies/evaluations targeted both biotic and abiotic media.

4) A PETS survey was performed by USDA-FS (Section C.2.2.1). The report documents findings of field surveys and literature reviews and determined the actual or potential occurrence of any PETS species in the project area. Results from the botanical and wildlife surveys did not identify any critical habitat nor located any PETS species within the project area (Attachment C-1).

5) SREL collected and analyzed biotic and abiotic samples within Dunbarton Bay (Section C.2.2.2). The findings show overall that levels of arsenic, selenium and strontium as well as uranium, copper and nickel in tissue were elevated in Dunbarton Bay when compared to the reference site. No population-level effects related to elevated body burdens were observed. In addition, the number of species in the Dunbarton Bay wetlands was comparable to a nearby reference bay, indicating that the elevated levels of metals are not adversely impacting the biodiversity of herpetofauana within Dunbarton Bay (Attachment C-2).

   Past SREL research in the D-Area system has assessed the effects of CCW on vertebrates. Previous studies have documented contaminant bioaccumulation, with accompanying individual-level effects (e.g., altered behavior, increased deformities, reduced growth) and population-level effects (e.g., reduced recruitment and offspring viability) in some species, with the most deleterious effects being associated with the highest level of contaminants (i.e., in active ash settling basins). In general, biological effects in the D-Area Ash Plume Wetland (DAPW) remain elevated compared to reference sites but are below levels observed for the primary and secondary ash basins. Similarly, trace element concentrations in surface sediments in the DAPW have attenuated compared to the DAB sediments. Both the forest plant community and the amphibian community have a species composition that appears to be "normal" for the type and age of the habitat. The trace element concentrations at Dunbarton Bay are lower than at the DAPW, and it also appears to have a typical amphibian community compared to the nearby reference site.

Therefore, the results of the site specific studies by SREL appears to indicate that the ash media at Dunbarton Bay does not represent a significant risk to populations/communities of ecological receptors.

6) Trophic-level modeling was conducted using the site-specific data that was collected and analyzed by SREL (Section C.2.2.3). This effort addressed the uncertainty associated with relying strictly on literature-base toxicity values and exposure assumptions. The results showed aluminum exceeded toxicity reference values for the raccoon and great blue heron in both the Dunbarton Bay wetlands and the reference site (Bay 100). Aluminum is known to be elevated across the SRS due to naturally high aluminum in soils at the SRS, and its presence in the reference bay indicates the elevated levels are not due to contributions from the ash deposits. This is observed by the data collected that showed levels in the reference bay (Bay 100) were higher than the Dunbarton Bay system. The trophic-level modeling report is provided in Attachment C-3.

7) A refinement of COPCs resulting from the screening levels effects evaluation (using the definitive level data collected in 2010) was performed in Section C.2.3.1. This re-evaluation concluded that although barium, selenium and thallium had LOAEL-based HQs >1, the concentrations of these naturally occurring constituents are within SRS background concentrations and therefore do not represent a significant risk issue. The concentration of arsenic is greater than SRS background, but it was identified a COPC for sediment dwelling organisms (HQ = 1.8) only.

8) The presence of surface water is highly variable; no surface water was present during the 2011 sampling events. Therefore, the surface water media does not represent a prolonged, sustainable source of exposure for aquatic/semi-aquatic wildlife receptors (Section 2.3.2.).

9) Three lines of evidence regarding the toxicity of the ash media is provided in Section C.2.3.3.

   - Although the most conservative ER-L screening values were exceeded for sediment dwelling organisms (arsenic and barium), the concentrations of these constituents do not exceed the ER-M value.

   - Given the surface water media does not represent a prolonged, sustainable source of exposure for aquatic/semi-aquatic wildlife receptors, it is probable that traditional benthic dwelling organisms do not exist within the Dunbarton Bay wetland.

   - Toxicity tests conducted on ash from the D-Area Wetlands using earthworm (representative of soil invertebrates) exposure did not cause significant mortality to the earthworms and the higher body burdens of several metals were not great enough to be biologically significant (Attachment C-4).

10) Related research conducted in ash depositional wetlands indicates that bioavailability of metals may be reduced in aged sediments from historic CCW deposits where surface leaching has occurred (C.2.3.4). In addition, the TCLP extractable contaminant levels for all ash impacted soils show no clear trends within the ash disposition zone in Dunbarton Bay.

C.2.5 ERA Conclusion

This ERA considers multiple lines-of-evidence in an effort to make a determination whether the ash media within Dunbarton Bay either has in the past or has the potential in the future to pose a significant risk to wildlife receptors. These lines-of-evidence include the following: chemical analysis of the impacted medium, literature-based risk calculations, bioaccumulation and field tissue surveys, trophic level modeling, population/community evaluations, and toxicity testing information.

There is no clear evidence that Dunbarton Bay is negatively impacting ecological receptors, as it appears that it is as healthy and diverse an ecosystem as compared to similar areas adjacent to it that are not contaminated. The overall weight-of-evidence leads to the conclusion that the naturally occurring trace metals associated with the coal ash that is present within the Dunbarton Bay system do not pose an unacceptable risk to representative populations inhabiting or utilizing the area or to special species of concern. Therefore no ecological RCOCs are identified and there are no problems warranting action from an ecological risk perspective. The preliminary CSM was revised based on this assessment and is presented in Chapter 1.

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Table C-1. Ecological Screening for Terrestrial Receptors at Dunbarton Bay (0 To 1 Ft)

Constituent	Detected Maximum Concentration[1]	ESV[2]	ESV Screen		Background Screen		COPC?[6]
			Screening Level HQ[3]	HQ >1?	2X Average Background[4]	Exceed Background?[5]	
Inorganics (mg/kg)							
Aluminum	6.97E+03	1.65E+01	422.1	YES	1.05E+04	No	No
Arsenic	3.36E+01	1.54E+00	21.9	YES	4.28E+00	YES	YES
Barium	1.44E+02	6.05E+01	2.4	YES	3.91E+01	YES	YES
Beryllium	2.08E+00	1.10E+00	1.9	YES	2.89E-01	YES	YES
Cadmium	2.24E-01	1.09E-01	2.1	YES	4.83E-01	No	No
Calcium	2.09E+03	Nutrient[7]	--	No	4.76E+02	--	No
Chromium	1.54E+01	4.59E+00	3.4	YES	1.54E+01	No	No
Cobalt	7.60E+00	2.00E+01	< 1	No	1.55E+00	--	No
Copper	5.58E+01	4.00E+01	1.4	YES	4.34E+00	YES	YES
Iron	1.42E+04	2.00E+02	71.0	YES	1.27E+04	YES	YES
Lead	1.36E+01	1.98E+00	6.9	YES	1.03E+01	YES	YES
Magnesium	3.60E+02	Nutrient[7]	--	No	2.75E+02	--	No
Manganese	3.54E+02	1.00E+02	3.5	YES	1.53E+02	YES	YES
Mercury	7.73E-02	3.00E-01	< 1	No	7.10E-02	--	No
Nickel	1.26E+01	3.00E+01	< 1	No	3.48E+00	--	No
Potassium	5.84E+02	Nutrient[7]	--	No	2.16E+02	--	No
Selenium	5.44E+00	4.24E-01	12.8	YES	2.99E+00	YES	YES
Silver	2.04E-01	2.00E+00	< 1	No	7.28E-01	--	No
Sodium	6.12E+01	Nutrient[7]	--	No	4.02E+01	--	No
Thallium	3.67E+00	1.24E-02	295.3	YES	3.12E+00	YES	YES
Vanadium	2.58E+01	1.44E+00	17.9	YES	3.91E+01	No	No
Zinc	5.50E+01	6.59E+00	8.3	YES	9.47E+00	YES	YES

1 - Maximum detected concentration from the 0- to1-ft ash interval.

2 - The Ecological Screening Value (ESV) is the lesser of the value in the ESV protocol (WSRC 2006) and the NOAEL-based ET (WSRC 2004, ERD-AG-2004-00001).

3 - The screening level HQ is determined by dividing the maximum concentration by the ESV.

4 - Background screening values obtained from *Background Soils Statistical Summary Report for Savannah River Site*, ERD-EN-2005-0223, Rev. 1, 10/06, Appendix B-1.

5 - Background screen performed only for anthropogenic inorganic constituents.

6 - Constituents are identified as COPCs if the maximum detected concentration exceeds the ecological screening value and the 2X average background concentration.

7 - Calcium, magnesium, potassium, and sodium are essential nutrients and are not identified as COPCs.

Table C-2. Maximum Concentration Hazard Quotient Evaluation for Terrestrial Receptors at Dunbarton Bay (0 To 1 Ft)

Constituent	Maximum Concentration *(mg/kg)*	Earthworm HQ	Shrew HQ		Mouse HQ		Raccoon HQ		Robin HQ		Hawk HQ	
			NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Inorganics												
Arsenic	3.36E+01	<1	**22**	**2.2**	**1.9**	<1	**4.8**	<1	<1	<1	<1	<1
Barium	1.44E+02	--	**2.4**	<1	<1	<1	<1	<1	<1	<1	<1	<1
Beryllium	2.08E+00	--	<1	<1	<1	<1	<1	<1	--	--	--	--
Copper	5.58E+01	**1.1**	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iron	1.42E+04	--	--	--	--	--	--	--	--	--	--	--
Lead	1.36E+01	<1	<1	<1	<1	<1	<1	<1	**6.9**	<1	<1	<1
Manganese	3.54E+02	--	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Selenium	5.44E+00	<1	**12.8**	**7.8**	<1	<1	1.2	<1	**10.3**	**5.1**	<1	<1
Thallium	3.67E+00	--	**295**	**30**	**2.7**	<1	**26**	**2.6**	**12.9**	1.3	<1	<1
Zinc	5.50E+01	<1	<1	<1	<1	<1	<1	<1	**8.3**	<1	<1	<1

Table C-3. Average Concentration Hazard Quotient Evaluation for Terrestrial Receptors at Dunbarton Bay (0 To 1 Ft)

Constituent	Average Concentration *(mg/kg)*	Earthworm HQ	Shrew HQ		Mouse HQ		Raccoon HQ		Robin HQ		Hawk HQ	
			NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Inorganics												
Arsenic	1.48E+01	<1	**9.6**	<1	<1	<1	**2.1**	<1	<1	<1	<1	<1
Barium	6.82E+01	--	**1.1**	<1	<1	<1	<1	<1	<1	<1	<1	<1
Beryllium	1.08E+00	--	<1	<1	<1	<1	<1	<1	--	--	--	--
Copper	2.07E+01	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iron	6.89E+03	--	--	--	--	--	--	--	--	--	--	--
Lead	8.48E+00	<1	<1	<1	<1	<1	<1	<1	**4.3**	<1	<1	<1
Manganese	9.42E+01	--	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Selenium	2.57E+00	<1	**6.1**	**3.7**	<1	<1	<1	<1	**4.8**	**2.4**	<1	<1
Thallium	1.67E+00	--	**134**	**13**	**1.2**	<1	**12**	**1.2**	**5.9**	<1	<1	<1
Zinc	2.08E+01	<1	<1	<1	<1	<1	<1	<1	**3.2**	<1	<1	<1

Table C-4. Ecological Screening for Aquatic Receptors at Dunbarton Bay (0 To 1 Ft)

Constituent	Maximum Concentration[1]	ESV[2]	Screening Level HQ[3]	HQ >1?	2X Average Background[4]	Exceed Background?[5]	COPC?[6]
Inorganics *(mg/kg)*							
Aluminum	6.97E+03	6.36E+01	109.6	yes	1.05E+04	no	no
Arsenic	3.36E+01	6.68E+00	5.0	yes	4.28E+00	yes	yes
Barium	1.44E+02	2.00E+01	7.2	yes	3.91E+01	yes	yes
Beryllium	2.08E+00	2.53E+01	< 1	no	2.89E-01	yes	no
Cadmium	2.24E-01	5.37E-01	< 1	no	4.83E-01	no	no
Calcium	2.09E+03	--	nutrient[7]	no	4.76E+02	yes	no
Chromium	1.54E+01	4.76E+01	< 1	no	1.54E+01	no	no
Cobalt	7.60E+00	2.00E+01	< 1	no	1.55E+00	yes	no
Copper	5.58E+01	1.87E+01	3.0	yes	4.34E+00	yes	yes
Iron	1.42E+04	--	--	no	1.27E+04	yes	no
Lead	1.36E+01	2.92E+01	< 1	no	1.03E+01	yes	no
Magnesium	3.60E+02	--	nutrient[7]	no	2.75E+02	yes	no
Manganese	3.54E+02	4.17E+03	< 1	no	1.53E+02	yes	no
Mercury	7.73E-02	1.30E-01	< 1	no	7.10E-02	yes	no
Nickel	1.26E+01	1.59E+01	< 1	no	3.48E+00	yes	no
Potassium	5.84E+02	--	nutrient[7]	no	2.16E+02	yes	no
Selenium	5.44E+00	1.38E+00	3.9	yes	2.99E+00	yes	yes
Silver	2.04E-01	1.00E+00	< 1	no	7.28E-01	no	no
Sodium	6.12E+01	--	nutrient[7]	no	4.02E+01	yes	no
Thallium	3.67E+00	3.99E-02	92.0	yes	3.12E+00	yes	yes
Vanadium	2.58E+01	5.31E+00	4.9	yes	3.91E+01	no	no
Zinc	5.50E+01	7.84E+01	< 1	no	9.47E+00	yes	no

1 - Maximum detected concentration from the 0- to 1-ft interval.
2 - The Ecological Screening Value (ESV) is the lesser of the value in the ESV protocol (WSRC 2006) and the NOAEL-based ET (WSRC 2004, ERD-AG-2004-00002).
3 - The screening level HQ is determined by dividing the maximum concentration by the ESV.
4 - Background screening values obtained from *Background Soils Statistical Summary Report for Savannah River Site*, ERD-EN-2005-0223, Rev. 1, 10/06, Appendix B-1.
5 - Background screen performed only for anthropogenic inorganic constituents.
6 - Constituents are identified as COPCs if the maximum detected concentration exceeds the ecological screening value and the 2X average background concentration.
7 - Calcium, magnesium, potassium, and sodium are essential nutrients and are not identified as COPCs.

Table C-5. Maximum Concentration Hazard Quotient Evaluation for Aquatic Receptors at Dunbarton Bay (0 To 1 Ft)

Constituent	Maximum Concentration *(mg/kg)*	Benthic Organisms HQ	Raccoon NOAEL-HQ	Raccoon LOAEL-HQ	Heron NOAEL-HQ	Heron LOAEL-HQ
Inorganics						
Arsenic	3.36E+01	**4.1**	**5.0**	< 1	< 1	< 1
Barium	1.44E+02	**7.2**	< 1	< 1	< 1	< 1
Copper	5.58E+01	**1.6**	< 1	< 1	< 1	< 1
Selenium	5.44E+00	--	**4.0**	**2.4**	< 1	< 1
Thallium	3.67E+00	--	**92**	**9.2**	**1.1**	< 1

Table C-6. Average Concentration Hazard Quotient Evaluation for Aquatic Receptors at Dunbarton Bay (0 To 1 Ft)

Constituent	Average Concentration *(mg/kg)*	Benthic Organisms HQ	Raccoon NOAEL-HQ	Raccoon LOAEL-HQ	Heron NOAEL-HQ	Heron LOAEL-HQ
Inorganics						
Arsenic	1.48E+01	**1.8**	**2.2**	< 1	< 1	< 1
Barium	6.82E+01	**3.4**	< 1	< 1	< 1	< 1
Copper	2.07E+01	< 1	< 1	< 1	< 1	< 1
Selenium	2.57E+00	--	**1.9**	**1.1**	< 1	< 1
Thallium	1.67E+00	--	**42**	**4.2**	< 1	< 1

Table C-7. Ecological Screening for Aquatic Receptors at Dunbarton Bay (Surface Water)

Constituent	Maximum Concentration[1]	ESV[2]	Screening Level HQ[3]	HQ >1?	COPC?
Inorganics (mg/L)					
Aluminum	1.93E+00	8.70E-02	2.22E+01	yes	yes
Antimony	4.54E-03	1.60E-01	2.84E-02	no	no
Arsenic	4.65E-02	2.68E-03	1.74E+01	yes	yes
Barium	9.35E-02	4.00E-03	2.34E+01	yes	yes
Calcium	1.73E+01	1.16E+02	1.49E-01	no	no
Chromium	7.65E-03	2.80E-02	2.73E-01	no	no
Cobalt	5.89E-03	2.30E-02	2.56E-01	no	no
Copper	5.07E-03	2.90E-03	1.75E+00	yes	yes
Iron	9.55E+00	1.00E+00	9.55E+00	yes	yes
Magnesium	2.94E+00	8.20E+01	3.59E-02	no	no
Manganese	2.77E-01	1.20E-01	2.31E+00	yes	yes
Nickel	7.27E-03	1.60E-02	4.54E-01	no	no
Potassium	5.92E+00	5.30E+01	1.12E-01	no	no
Sodium	7.48E+00	6.80E+02	1.10E-02	no	no
Vanadium	2.50E-02	2.00E-02	1.25E+00	yes	yes
Zinc	3.31E-02	3.70E-02	8.95E-01	no	no

1 - Maximum detected concentration in surface water.
2 - The Ecological Screening Value (ESV) is the lesser of the value in the ESV protocol (WSRC 2006a), the NOAEL-based ET (WSRC 2004, ERD-AG-2004-00003) and the April 2008 SCDHEC Water Quality Standards (chronic values).
3 - The screening level HQ is determined by dividing the maximum concentration by the ESV.

Table C-8. Maximum Concentration Hazard Quotient Evaluation for Aquatic Receptors at Dunbarton Bay (Surface Water)

Constituent	Maximum Concentration *(mg/L)*	Benthic Organisms HQ	Raccoon NOAEL-HQ	Raccoon LOAEL-HQ	Heron NOAEL-HQ	Heron LOAEL-HQ
Inorganics						
Aluminum	1.93E+00	**2.22E+01**	**1.76E+00**	1.76E-01	1.93E-02	1.93E-03
Arsenic	4.65E-02	3.10E-01	**1.74E+01**	**1.74E+00**	2.54E-01	1.02E-01
Barium	9.35E-02	**2.34E+01**	1.38E-02	3.56E-03	2.25E-03	1.12E-03
Copper[1]	5.07E-03	**1.75E+00**	1.53E-02	1.16E-02	2.28E-03	1.74E-03
Iron	9.55E+00	**9.55E+00**	--	--	--	--
Manganese	2.77E-01	**2.31E+00**	2.11E-01	6.55E-02	1.11E-02	1.14E-03
Vanadium	2.50E-02	**1.25E+00**	1.00E-02	1.00E-03	2.23E-04	2.23E-05

1 - Water Quality Standard for aquatic organisms based on default hardness of 25 mg/L as $CaCO_3$.
-- = No ecological threshold calculated

Table C-9. Radiological Ecological Screening for Terrestrial Receptors at Dunbarton Bay (0 To 1 Ft)

Constituent	Detected Maximum Activity[1]	Radiological Benchmark Value[2]	Benchmark Screen		Background Screen		COPC?[6]
			Screening Level HQ[3]	HQ >1?	2X Average Background Activity[4]	Exceed 2X Average Background?[5]	
Radionuclides (pCi/g)							
Actinium-228	2.50E+00	1.36E+02	1.84E-02	no	1.95E+00	YES	no
Cesium-137	5.19E+00	2.39E+02	2.17E-02	no	2.84E-01	YES	no
Potassium-40	1.64E+01	3.63E+02	4.52E-02	no	2.33E+00	YES	no
Radium-226	2.38E+00	6.01E+01	3.96E-02	no	1.37E+00	YES	no
Radium-228	2.50E+00	1.69E+04	1.48E-04	no	1.92E+00	YES	no
Thorium-228	2.21E+00	5.31E+01	4.16E-02	no	1.97E+00	YES	no
Thorium-230	2.71E+00	6.15E+01	4.41E-02	no	1.13E+00	YES	no
Thorium-232	2.29E+00	7.20E+01	3.18E-02	no	1.80E+00	YES	no
Uranium-233/234	2.40E+00	5.96E+01	4.03E-02	no	1.15E+00	YES	no
Uranium-235	1.76E-01	6.18E+01	2.85E-03	no	7.98E-02	YES	no
Uranium-238	2.51E+00	6.86E+01	3.66E-02	no	1.01E+00	YES	no

1 -Maximum detected concentration from the 0- to 1-ft ash interval.
2 -Radiological benchmark screening values for terrestrial receptor populations exposed to soil is set at 0.01 rad/day. Radiological benchmark values obtained from the Periodic Report 2 for the Steel Creek Integrator Operable Unit (WSRC 2004).
3 -The screening level HQ is determined by dividing the maximum activity by the benchmark screening value.
4 -Background screening values obtained from *Background Soils Statistical Summary Report for Savannah River Site*, ERD-EN-2005-0223, Rev. 1, 10/06, Appendix B-1.
5 -For screening purposes, maximum concentration of the naturally-occurring (nonanthropogenic) constituents are compared to 2X average background activity.
6 -Constituents are identified as COPCs if the maximum detected activity exceeds the radiological benchmark value and the 2X average background activity.

Table C-10. Radiological Ecological Screening for Aquatic Receptors at Dunbarton Bay (0 To 1 Ft)

Analyte	Detected Maximum Activity[1]	Radiological Benchmark Value[2]	Benchmark Screen		Background Screen		COPC?[6]
			Screening Level HQ[3]	HQ >1?	2X Average Background Activity[4]	Exceed 2X Average Background?[5]	
Radionuclides (pCi/g)							
Actinium-228	2.50E+00	5.37E+03	4.66E-04	no	1.95E+00	YES	no
Cesium-137	5.19E+00	8.73E+03	5.95E-04	no	2.84E-01	YES	no
Potassium-40	1.64E+01	3.34E+04	4.91E-04	no	2.33E+00	YES	no
Radium-226	2.38E+00	7.45E+05	3.19E-06	no	1.37E+00	YES	no
Radium-228	2.50E+00	5.21E+05	4.80E-06	no	1.92E+00	YES	no
Thorium-228	2.21E+00	1.74E+06	1.27E-06	no	1.97E+00	YES	no
Thorium-230	2.71E+00	2.61E+06	1.04E-06	no	1.13E+00	YES	no
Thorium-232	2.29E+00	5.21E+06	4.40E-07	no	1.80E+00	YES	no
Uranium-233/234	2.40E+00	2.61E+06	9.20E-07	no	1.15E+00	YES	no
Uranium-235	1.76E-01	3.34E+04	5.27E-06	no	7.98E-02	YES	no
Uranium-238	2.51E+00	5.21E+06	4.82E-07	no	1.01E+00	YES	no

1 -Maximum detected concentration from the 0- to 1-ft ash interval.
2 -Radiological benchmark screening values for terrestrial receptor populations exposed to soil is set at 0.01 rad/day. Radiological benchmark values obtained from the Periodic Report 2 for the Steel Creek Integrator Operable Unit (WSRC 2004).
3 -The screening level HQ is determined by dividing the maximum activity by the benchmark screening value.
4 -Background screening values obtained from *Background Soils Statistical Summary Report for Savannah River Site*, ERD-EN-2005-0223, Rev. 1, 10/06, Appendix B-1.
5 -For screening purposes, maximum concentration of the naturally-occurring (nonanthropogenic) constituents are compared to 2X average background activity.
6 -Constituents are identified as COPCs if the maximum detected activity exceeds the radiological benchmark value and the 2X average background activity.

Table C-11. Radiological Ecological Screening for Aquatic Receptors at Dunbarton Bay (Surface Water)

Analyte	Detected Maximum Activity[1]	Radiological Benchmark Value[2]	Benchmark Screen		Background Screen		COPC?[6]
			Screening Level HQ[3]	HQ >1?	2X Average Background Activity[4]	Exceed 2X Average Background?[5]	
Radionuclides (pCi/L)							
Radium-226	5.31E-01	4.08E+05	1.30E-06	no	NA	NA	no

1 -Maximum detected activity in the surface water.
2 -Radiological benchmark screening values for aquatic receptor populations exposed to surface water is set at 0.1 rad/day. Radiological benchmark values obtained from the *Periodic Report 2 for the Steel Creek Integrator Operable Unit* (WSRC 2004).
3 -The screening level HQ is determined by dividing the maximum activity by the benchmark screening value.
NA - not available

Attachment C-1

**Habitat Assessment and Proposed,
Threatened, Endangered, and Sensitive (TES) Species Survey
for the P-Area Ash Basin and Dunbarton Bay Wetland**

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Habitat Assessment and Proposed, Endangered, Threatened and Sensitive Species Survey for the P-Area Ash Basin and Dunbarton Bay Wetland

United States Department of Agriculture Forest Service-Savannah River

LOCATION:

Barnwell, County, SC

Savannah River Site

Contact Person: Charlie Davis, (803) 725-8620

Submitted by:

Charlie Davis - Ecologist

USDA Forest Service-Savannah River

May 2012

Reviewed by: _______________ Date: 5/04/2012

FM Peggy Anderson, Assistant Forest Manager, Natural Resources

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LIST OF ABBREVIATIONS AND ACRONYMS

ACP	Area Completion Project
DB	Dunbarton Bay wetland
ESA	Endangered Species Act
GIS	Geographical Information System
IOU	Intergrator Operable Unit
LIDAR	Light Detection And Ranging
NRMP	Natural Resource Management Plan
RCW	Red cockaded woodpecker
PAB	P Area Ash Basin
PAPW	P-Area Ash Plume Wetland
PETS	Protected, Endangered, Threatened, and Sensitive species
ROW	Rights-of-Way
SCDNR	South Carolina Department of Natural Resources
SOC	Species of Concern
SRS	Savannah River Site
SREL	Savannah River Ecology Laboratory
SRNS	Savannah River Nuclear Solutions
TES	Threatened, Endangered, Sensitive
USDA-FS SR	United States Department of Agriculture Forest Service - Savannah River
USDOE	United States Department of Energy
USFWS	United States Fish and Wildlife Service

I. Introduction

Historical waste operations associated with the United States Department of Energy's Savannah River Site's (USDOE-SRS)
P-Area Ash Basin (PAB) resulted in overflow and deposition of coal fly ash into the down-gradient wetlands of Dunbarton Bay (DB; SRS Carolina Bay No. 96). The DB functions as a seasonal wetland and contains a plume of coal ash referred to as the P-Area Ash Plume Wetland (PAPW). Coal ash deposition in these wetlands ranges in depth from up to a meter in places and poses a potential ecological risk because the DB represents a pathway for the release of contaminants into the environment (SRNS, 2011). Characterization of this wetland is necessary to determine the nature and extent of the contamination and to support future remedial action decisions: any remedial actions would require an environmental assessment of the impacted area.

In support of this characterization, the United States Department of Agriculture - Forest Service Savannah River (USDA-FS SR) was tasked to conduct a habitat assessment and a Proposed (P), Endangered (E), Threatened (T), and Sensitive (S) species (PETS) survey within the impacted area leading from the PAB and into the DB to assess potential threats or critical habitats for species of conservation concern. This report documents the findings of field surveys and literature reviews to determine the actual or potential occurrence of any PETS species in the impacted project areas.

II. Project Survey Area Location and Description

The PAB and DB/PAPW assessment area is located near the headwaters of the Meyers Branch drainage in the USDA-FS SR's Timber Compartment 74 (Fig. 1). Timber Compartment 74 is within the Steel Creek IOU and is part of the USDA FS -SR's Steel Creek Administrative Watershed as well as the USDOE-SRS's Supplemental Red-cockaded Woodpecker (RCW) Habitat Management Area (USDA-FS SR NRMP, 2005). More specifically, the ash deposition area involved in this investigation is south of the PAB and Power Line Road (also referred to as Ash Flow Road, SRS Road 74-28) and portions of the DB north of B-Road (Fig. 2). The extent of the impacted area is approximately of 16.2 hectares (40 acres) in size and is comprised of portions of timber stands 38, 46, and 77. The survey area is predominantly flat containing disturbed and undisturbed upland areas that grades into the depositional DB wetland. Three habitat types exist within the survey area; these include: 1) 3.04 hectares (7.5 acres) of disturbed and undisturbed portions of a maturing pine and mixed pine hardwood upland and mesic forest; 2) 0.81 hectares (2.0 acres) of upland early successional vegetation along roadside and utility corridor rights-of-ways (ROW); and 3) approximately 12.3 hectare (30.5 acres) of disturbed (overburden of ash deposition) and undisturbed portions of a maturing mixed bottomland and cypress swamp forests. Upland soils down gradient and associated with the PAB are of the Udorthents, Blanton and Fuquay series; hydric soils delineated in the primary impact areas of the DB and the PAPW are of the Pickney series (Rogers, 1990; see Appendix A).

III. PETS Species Considered for Survey

USDA FS-SR staff conducted a review of site records, including historical and recent aerial photographs, LIDAR imagery, timber stands data, soils information, and existing records for PETS species to determine if any were present in the project area. A list of PETS species having potential to occur in the area was then identified based on the presence of required habitat elements. This PETS species listing was compiled from Blake and Kilgo (2005) to provide the most current information within the vicinity of the survey area. Efforts were then made to identify any potential conflicts with PETS species as defined or listed by the U. S. Fish and Wildlife Service (USFWS), which are protected under the 1973 Endangered Species Act (ESA). *Proposed* is a category which includes taxon that are proposed for listing as endangered or threatened. *Endangered* refers to a taxon that is in danger of extinction throughout all or a significant portion of its range. *Threatened* status includes taxa that are likely to become endangered within all or a significant portion of their range. *Sensitive* species include taxa for which population viability is a concern. Sensitive species are not protected under the ESA; however, some of the animal species are protected under the South Carolina Non-game and Endangered Species Conservation Act. The purpose of identifying sensitive species is to ensure viability and to prevent any trend toward endangerment that would result in the need for federal listing under the ESA.

The SRS has five federally listed Endangered species (2 plants, 3 animals), three Threatened and Protected species, one Candidate species, and 71species (41 plants, 30 animals) that are not listed but considered Sensitive on the SRS (see Table 1 below). All were considered for analysis in this survey document.

Endangered Species

Federally listed species on the SRS include the smooth coneflower (*Echinacea laevigata*), pondberry (*Lindera melissifolia), s*hort-nose sturgeon (*Acipenser brevirostrum*), wood stork (*Mycteria americana*), and red cockaded woodpecker (RCW; *Picoides borealis*).

Threatened and Protected Species

Federally recognized species are the bald eagle (*Haliaeetus leucocephalus*) which is protected under the Bald and Golden Eagle Protection Act, and the American alligator (*Alligator mississippiensis*) which is considered threatened due to similarity of appearance with other Crocodilian species.

Candidate Species

The gopher tortoise (*Gopherus polyphemus*) was recently added on July 27, 2011 to the list of candidate species eligible for the ESA (USFWS 2011).

The following Table is a list of sensitive species recognized on the SRS.

Table 1. Sensitive Species Recognized on the SRS With Their Global Rankings and State and ESA Status (Taken From Kilgo and Blake [2005] and SCDNR [2012])

Common Name	Scientific name	Global Ranking	State Ranking	State Protection	ESA Designation
Sensitive Plants					
Striped garlic	*Allium cuthbertii*	G4	S2		
Gerardia	*Agalinus decemloba*	G3	S1		
Incised groovebur	*Agrimonia incisa*	G3	S1		
Dutchman's pipe	*Aristolochia macrophylla*	G5	S3		
Great Indian plantain	*Arnoglossum muehlenbergii*	G4	S1		
Beaded milkvetch	*Astragalus villosus*	G4	S1		
Sandhills milkvetch	*Astragalus michauxii*	G3	S3		
Lanceleaf wild indigo	*Baptisia lanceolata*	G4	S3		
Chapman's sedge	*Carex chapmanii*	G3	S1		
Collin's sedge	*Carex collinsii*	G3	S1		
Cypress-knee sedge	*Carex decomposita*	G3	S2		
Eastern few-fruit sedge	*Carex oligocarpa*	G4	S2		
Nutmeg hickory	*Carya myristiciformis*	G4	S1		
Rose coreopsis	*Coreopsis rosea*	G3	S2		
Elliot's croton	*Croton elliottii*	G2G3	S2S3		
Carolina larkspur	*Delphinium carolinianum*	G3	S1		
Little bur-head	*Echinodorus tenellus var parvulvus*	G3	S2		
Southern swamp privet	*Foresteria acuminata*	G4	S1		
Green-fringe orchid	*Platanthera lacera*	G5	S1		
Two-wing silverbell	*Halesia diptera*	G5	S1		
Little silverbell	*Halesia parviflora*	G3	S2		
Bog spicebush	*Lindera subcoriacea*	G2G3	S3		
Boykin's lobelia	*Lobelia boykinii*	G2G3	S3		
Spathulate seedbox	*Ludwigia spathulata*	G2G4	S2		
Carolina birds-in-a-nest	*Macbridea caroliniana*	G2G3	S3		
Canada moonseed	*Menispermum canadense*	G4	S1		
Indian olive	*Nestronia umbellula*	G4	S2		
Sandhill lily	*Nolina georgiana*	G3G5	S3		
American nailwort	*Paronychia americana*	G3G4	SNR		
Durand oak	*Quercus durandii*	G5	S1		
Three-awned meadow beauty	*Rhexia aristosa*	G3	S2		
West Indies meadow beauty	*Rhexia cubensis*	G3	S1		
Oconee azalea	*Rhododendron flammeum*	G3	S2		
Drowned horned rush	*Rhynchospora inundata*	G3G4	S1		
Slender arrowhead	*Sagittaria isoetiformis*	G3G4	S2		
Sweet pitcher plant	*Sarracenia rubra*	G3	S1		
Canby's bulrush	*Scirpus etuberculatus*	G3G4	S1		
Baldwin's nut rush	*Scleria baldwinii*	G4	S1S2		
Least trillium	*Trillium pussilum*	G3T2	S1		
Florida bladderwort	*Utricularia floridana*	G3G5	S2		
Dwarf bladderwort	*Utricularia olivacea*	G4	S2		
Sensitive Animals					
Southeastern bat	*Myotis austroriparius*	G3G4	S1		
Little brown bat	*Myotis lucifugus*	G5	S3?		
Rafinesque's big-eared bat	*Corynorhinus rafinesquii*	G3G4	S2?	E	
Star nosed mole	*Condylura cristata*	G5	S3?		
Eastern woodrat	*Neotoma floridana*	G5	S3S4		
Swamp rabbit	*Sylvilagus aquaticus*	G5	S3		
Black bear	*Ursus americanus*	G5	S3		
Swallow-tailed kite	*Elanoides forficatus*	G5	S2	E	SC
American kestrel	*Falco sparverius*	G5	S4		
Common ground dove	*Columbina passerina*	G5	S?		
Loggerhead shrike	*Lanius ludovicianus*	G5	S3		

Table 1. Sensitive Species Recognized on the SRS With Their Global Rankings and State and ESA Status (Taken From Kilgo and Blake [2005] and SCDNR [2012]) *(Continued/End)*

Common Name	Scientific name	Global Ranking	State Ranking	State Protection	ESA Designation
Sensitive Animals *(Contd)*					
Swainson's warbler	*Limnothlypis swainsonii*	G4	S4		
Painted bunting	*Passerina ciris*	G?	S?		
Henslow's sparrow	*Ammodramus henslowii*	G?	S?		
Bachman's sparrow	*Aimophila aestivalis*	G3	S5		
Tiger salamander	*Ambystoma tigrinum*	G5T5	S2S3		
Gopher frog	*Rana capito*	G3	S1	E	
Southern hognose snake	*Heterodon simus*	G2	SNR		
Florida green water snake	*Nerodia floridana*	G5	S2		
Pine snake	*Pituophis melanoleucus*	G4	S3S4		
Eastern coral snake	*Micrurus fulvius*	G5	S2		
Atlantic sturgeon	*Acipenser oxyrinchus*	G3	S3		
Brook floater	*Alasmidonta varicosa*	G3	S?		
Brother spike mussel	*Elliptio fraterna*	G1G2	S1		
Mill Creek elliptio	*Elliptio hepatica*	GNR	SNR		
Yellow lance	*Elliptio lanceolata*	G3G4	S2		
Yellow lamp mussel	*Lampsilis splendida*	G3	S2		
Savannah lilliput	*Toxolasma pullus*	G2	S1S3		
Notched rainbow mussel	*Villosa constricta*	G3	S?		
Sand-burrowing mayfly	*Dolania americana*	GNR	SNR		

Nature Conservancy and South Carolina Department of Natural Resources rarity/vulnerability rankings used on the SRS.

Ranking[a]	Definition
G1	Critically imperiled globally due to worldwide extreme rarity
G2	Imperiled globally due to worldwide rarity
G3	Either very rare throughout its range or found locally in a restricted range, or having factors making it vulnerable
G4	Apparently secure globally, though it may be rare in parts of its range
G5	Demonstrably secure globally, though it may be rare in parts of its range
S1	Critically imperiled state-wide because of extreme rarity or because of some factors making it especially vulnerable to extirpation; or fewer than 6 occurrences in the state
S2	Imperiled state-wide because of rarity or factors making it vulnerable, or 7-20 occurrences in the state
S3	Rare or uncommon in state; or 21-100 occurrences in the state
S4	Apparently secure in state; or <100 occurrences in the state
S5	Demonstrably secure in state
S?	South Carolina Heritage Trust has not assigned species a S ranking such as S1 to S5
Q	Questionable taxonomy which may reduce conservation priority

[a] Combined rankings such as S2S3 or G3G4 denote borderline species; for example, a species ranked S2S3 could be considered as possibly S2 or S3.
T Infraspecific Taxon (trinomial): The status of infraspecific taxa (subspecies or varieties) are indicated by a "T rank" following the species' global rank.

IV. Survey Methods

Botanical surveys and wildlife habitat assessments were conducted within the survey area on June 16-17 and October 25, 2011. This survey and assessment consisted of walking the survey area habitats in a stratified meander along loosely defined transects approximately 25 meters apart within and across the different habitat types. Field notes documented plant community and habitat types and those plant species that composed them. Wildlife sightings and/or sign such as browse, tracks, scat, and vegetation markings were also recorded. Avian surveys were conducted across the survey habitats by USDA FS-SR personnel (C. Davis, T. Grazia, and T. Thatcher) during the morning hours of July 27 and August 25, 2011. These bird vocalization counts were conducted from a total of seven points within and across the habitat types. Additional data considered for this report were the herpetological surveys conducted by the University of Georgia's Savannah River Ecology Laboratory (SREL) as part of the characterization of the DB (Seamans et al., 2012 unpublished report). Sampling methods used for herpetofauna were drift fencing and buckets. (Fig.9).

V. Flora and Fauna Observations and Field Survey Results

Field surveys within the survey area found little in the way of specialized, either unique/sensitive habitats. Rather, it was obvious there was habitat disturbance from sediment erosion and coal ash deposition from below the PAB and into the DB/PAPW wetland. Several factors may have limited the survey causing some degree of uncertainty with the findings. Conducting the survey during mid-summer meant that many of the migratory birds no longer vocalized or had migrated elsewhere. In addition, plant vegetative and flower production may have occurred prior to the survey during the spring months making it difficult to locate previously unknown PETS plant populations. Some rare plants can be easily overlooked without very thorough searches covering the ground systematically several times during the growing season, but such methods are not usually practical.

Flora Observations

Figures 4-6 illustrates the vegetation communities that compose the habitats types and stand conditions in the vicinity of the survey area. Within the disturbed and undisturbed portions of a maturing mixed pine hardwood upland and bottomland forest, the canopy vegetation is indicative of disturbance and is comprised of sweetgum, hackberry, loblolly pine, sweet bay, sycamore, red maple, water oak , box elder, and a number of dead and dying yellow poplars (Fig. 4). Shrub layer consisted of dense patch of Chinese privet, beauty berry and American holly. Forbs and grasses included pokeweed, fern spp., Smilax spp., blackberry patches, and the invasive Japanese stilt grass. A small area of maturing pine lies immediately to the south and east of the PAB and is dominated by loblolly pine as well as volunteer hardwoods such as sweetgum, water oak, southern red oak, and mockernut hickory. A dense understory lies along the margin of and beneath the mixed canopy and is dominated by typical mid-successional shrubs, vines, and herbs.

The vegetation within the roadside and utility line corridor ROW to the south of the PAB is predominantly upland grass-forb open field species but also included some species associated with low lying areas (Fig. 5). Common upland old field species include: rattlebox, goldenrod verbena spp., knotgrass, and other annuals associated with the very early successional stages such as Johnson grass, honeysuckle, dog fennel, Chinese privet, poke berry, panicum grass, vitas sp., ferns, plumgrass, pepper vine, fleabane, thistle, milkweed and species of *Andropogon, Erigeron*, *Coreopsis*, *Desmodium, Lespedeza*, and *Eupatorium.* Low lying areas include common mullein, chain fern, meadow beauty, and various sedges and rushes. Also found in the both upland and low lying areas within the ROWs are woody species such as blackberry, poison ivy and blueberry patches, trumpet vine, wax myrtle, muscadine, chinaberry, and seedlings and saplings of pine and various hardwood species, primarily hackberry, sweetgum and black cherry.

Figures 6 and 7 are habitat shots showing a mosaic of disturbed and undisturbed portions of a maturing mixed bottomland and cypress/tupelo swamp forests. The area is dominated by sweetgum, loblolly pine, sycamore, red maple, and yellow poplar before it transitioned into pond cypress and swamp tupelo. In the understory, peppervine, Chinese privet, muscadine, sweetbay, holly, switch cane, hackberry, and honeysuckle were found. Where there was noticeable overburden of ash sediment, there was a reduced understory with the exception of Japanese stiltgrass. Appendix B provides a list of common non-PETS species recorded during the habitat assessment and survey.

PETS plant species previously located within a two mile radius of the survey area are: Florida bladderwort, drowned horned rush, spatulate seedbox, and Sandhill lily (USDA FS-SR GIS TES plant layer). The semi-aquatic habitat associated with the DB wetland may provide some limited habitat to these species, however, none of these species were found during this survey period. The Florida bladderwort (USFS-SR TES pop. No. 218), a sensitive plant species was located in the DB impact area in a May 1992 PETS survey (Gaddy et al, USDA FS-SR contractor), but was not relocated during this recent TES survey (see Fig. 8). The present habitat conditions have undoubtedly changed since 1992 as there is no longer suitable open water habitat and open canopy conditions which this sensitive species prefers.

The DB wetland could provide some marginally suitable habitat for the endangered pondberry but the disturbed forest floor substrate and present representative understory suggests it would be minimal at best and the presence of this plant is unlikely.

Upland plants found along transitional mesic slopes and floodplain areas such as green-fringed orchid, Oconee azalea, nestronia, or bog spice bush are also unlikely since no appropriate habitat appears to exist in the survey area.

There is a very small potential, given the small area, for suitable soils and habitat along the ROW for upland sandhills species such as striped garlic, Sandhill lily, smooth coneflower, and wild-indigo, but no plants of these species were found.

Fauna Observations

The survey did reveal limited marginal to suitable habitat for some sensitive animal species. There is suitable habitat within the survey area for some small mammals and their associated predators (avian, mammalian and reptilian), birds that feed at ground level on insects and small seeds, and insectivorous birds and bats that feed on the wing. Suitable habitat exists for the star-nosed mole, southeastern bat, Rafinesque's big-eared bat, and little brown bats. These sensitive animals could potentially occur in one or more of the habitats in vicinity of the survey area. The star-nosed mole is associated with habitats in and near the DB bottomland hardwood forests that have moist to wet soils and the southeastern bat, Rafinesque's big-eared bat, and little brown bat may potentially roost in nearby P-Area structures and forage throughout the DB/PAPW survey area.

Avain surveys did not record any federally listed species. Bird species heard or seen within the upland PAB and ROW habitats included chimney swift, indigo bunting, pine warbler, tufted titmouse, red-eyed vireo, white-eyed vireo, northern cardinal, Carolina wren, pileated woodpecker, Carolina chickadee, blue jay, downy woodpecker, red-bellied woodpecker, yellow-billed cuckoo, white-breasted nuthatch, and mourning dove.

Within the DB/PAPW wetland area, birds heard, observed, or seen evidence of were the eastern towhee, tufted titmouse, wild turkey, mourning dove, blue jay, northern flicker, American crow, Carolina chickadee, Carolina wren, yellow-billed cuckoo, white-eyed vireo, summer tanager, pileated woodpecker, pine warbler, barred owl, downy woodpecker, red-bellied woodpecker, white-breasted nuthatch, and Mississippi kite. Of special note is the hearing of the Acadian flycatcher which is considered a priority species for the South Carolina State Comprehensive Wildlife Conservation Plan as well as the re-recording of the Mississippi kites seen flying over the survey area. The Mississippi kite was recorded during a former PETS survey of this area (see Bumpus and Garner, USDA FS-SR, 1994). Mississippi kites primarily feed on insects with a preference for grasshoppers, cicadas, dragonflies, and other insects that they will, at times, catch in flight and consume in midair. They sometimes will feed on small snakes, lizards, frogs and small birds. It may be important to note that while no nesting activity for this species was observed in survey area, it is possible/probable they may feed on insects and other birds and amphibians that might inhabit the PAB/DB project area.

In the PAB and ROW habitats area there was evidence of deer browse and hog activity, primarily rooting and wallowing in wet areas. In the DB and PAPW there was evidence of deer reproductive behavior (Fig. 9) and wild turkey feeding. Whether or not the area supports an ecological risk for these species is beyond the scope of this report.

To date, SREL's capture survey has yielded no listed species or any of state special concern, and concluded that the impacted area in the DB did not provide suitable habitat for sensitive species such as tiger salamanders or gopher frogs (David Scott, SREL personal communication). The following species list of the herpetofauna and mammals collected in the DB by SREL in the summer of 2011 was provided by the ACP.

Amphibians		**Reptiles**	
mole salamander	*Ambystoma talpoideum*	eastern mud turtle	*Kinosternon subrubrum*
marbled salamander	*A. opacum*	green anole	*Anolis carolinensis*
slimy salamander	*Plethodon glutinosus*	southern fence lizard	*Sceloporus undulatus*
eastern spadefoot toad	*Scaphiopus holbrookii*	ground skink	*Scincella laterale*
southern toad oak toad	*Bufo terrestris*	five-lined skink	*Eumeces fasciatus*
southern cricket frog	*Acris gryllus*	northern brown snake	*Storeria dekayi*
eastern narrow-mouthed toad	*Gastrophryne carolinensis*	southern ringneck snake	*Diadophis punctatus*
bullfrog	*Rana catesbeianna*		
green frog	*R. clamitans*	**Mammals**	
southern leopard frog	*R. sphenocephala*	southeastern shrew	*Sorex longirostris*
		short-tailed shrew	*Blarina brevicauda*
		mouse	*Peromyscus sp*
		eastern mole	*Scalopus aquaticus*

VI. Summary and Conclusion

In support of the characterization of the PAB/DB/PABW project area, the USDA FS-SR was tasked with conducting a habitat assessment and PETS survey. Determination of presence or likelihood of presence of PETS in the PAB/DB/PAPW survey area was made based on historical records, conversations with subject matter experts, literature searches of life history and habitat requirements, site visits and contracted plant surveys, and best professional judgment. Natural resource specialists (biologists, ecologists, and/or botanists) within the USDA FS-SR visited or had surveys conducted within the PAB/DB/PAPW survey area. Where information was lacking or absent, the best scientific and commercial data was utilized. This report documents the findings of field surveys and literature reviews and determined the actual or potential occurrence of any PETS species in the impacted project areas. Results from botanical and wildlife surveys did not identify any critical habitat nor located any PET species within the project area.

Based upon the above reviews, it was determined that the habitats in the vicinity of the PAB/DB/PAPW survey are generally not suitable for most SRS listed plant and animal PETS species. Compartment 74 lies within the Supplemental RCW Habitat Management Area and thus is not managed for priority nesting habitat for the RCW. This means the RCW is likely absent in the survey area and not expected to occur here in the foreseeable future. Currently the only potential RCW nesting habitat is in the upland habitat above the ROW. A portion of this area (approximately .6 ha (1 acre) is in maturing loblolly pine stand which is currently marked for an intermediate thinning harvest. This stand will be regenerated (clearcut) at 50 years of age and therefore will be unsuitable for any RCW nesting habitat. Suitable riverine habitat for the short nosed sturgeon is not available and other aquatic species such as the American sand burrowing mayfly are also highly unlikely. Some species, such as the bald eagle and American alligator may move across or briefly through the area as transients but no habitat conditions exist in the project survey area to support these species. There is no suitable sandhill habitat for the gopher tortoise or wetland habitat for the state (SC) endangered gopher frog. There is no suitable aquatic foraging or nesting habitat for the wood stork. There are three (3) known coneflower populations on the SRS, however, none occur in the PAB/DB/PAPW project area and therefore would not be a concern. The smooth coneflower is sometimes found in open ROW habitats that have suitable soils, however, the soils are primarily hydric within the utility and road ROW survey area making it unlikely for the establishment of this species.

A single pondberry population exists on the SRS along the margin of a Carolina bay located well away from the PAB/DB/PAPW project area and therefore would not be a concern. With the possible exception of pondberry habitat most commonly associated with wetland depressions with open canopies, there is no critical habitat designated for PETS plant species within the PAB/DB/PAPW assessment area. The Florida bladderwort, a sensitive plant species reported in the DB 20 years ago was not relocated in this survey likely due to the lack of open water and closed canopy habitat conditions. USDA-FS SR bird counts of the survey recorded 27 species, one of which is considered a species of conservation concern by the SCDNR.

As part of the habitat characterization, game and non-game wildlife species that were heard, seen, captured or evidence observed of wildlife utilizing the project area were recorded. Evidence of big game such as white-tailed deer, feral hogs, and wild turkey were observed in the survey area. Based on SREL's survey data, seventeen species of herpetofuana and two mammal species were captured but did not include any federally or state listed PETS species.

It is beyond the scope of this report to ascertain whether there are demonstrable or probable impacts to any known or unknown flora and fauna PETS species associated with the PAPW as a result of the coal ash deposition from the PAB.

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Appendix A
Soils of the Survey Area

The SRS soils survey (Rogers 1990) supplied the following soils information.

Udorthent soils (friable substratum) are associated with the PAB; these soils typically occur as spoil from excavated areas, disturbed areas, and borrow pits of friable soil materials. Permeability is dominantly moderate but ranges from moderately slow to rapid in Udorthents; the strongly to extremely acid character makes them very low in organic nutrients; they possess a low available water capacity.

Fuquay sand (2 to 6 percent slopes) is a well-drained soil found on broad ridges and side slopes of the Coastal Plain. This soil has a low organic matter content and a low available water capacity. It is moderately to very strongly acidic throughout. Permeability is slow in the lower part of the subsoil. This soil is well suited to habitat for open land wildlife, fairly suited for woodland habitat and very poorly suited for wetland wildlife habitat (Rogers, 1990).

Blanton sand (0 to 6 percent slopes) is somewhat excessively drained soils found on broad upland swales and low-lying ridges and side slopes of the Coastal Plain and Sand Hills. This soil has a low organic matter content, very low available water capacity, and is moderate to very strongly acidic in the surface layer.

Pickney loamy fine sands are characterized as very poorly drained and frequently flooded. They have 0-2 percent slopes, are extremely to moderately acidic, and are typically found in flats, depressions, stream terraces, and flood plains of the Sandhills and Coastal Plain.

Appendix B

List of Referenced Species (with common name; plant nomenclature follows Radford et al. (1987)

Trees	
American Holly	*Ilex Opaca*
Black Cherry	*Prunus Serotina*
Black Gum	*Nyssa Sylvatica*
Hackberry	*Celtis Occidentalis*
Loblolly Pine	*Pinus Taeda*
Mockernut Hickory	*Carya Tomentosa*
Persimmon	*Diospyros Virginianus*
Sweet Bay	*Magnolia Virginiana*
Sassafras	*Sassafras Albidum*
Southern Red Oak	*Quercus Falcata*
Sweetgum	*Liquidambar Styraciflua*
Water Oak	*Quercus Nigra*
Winged Elm	*Ulmus Alata*
Box Elder	*Acer Negundo*
Sycamore	*Platanus Occidentalis*
Pond Cypress	*Taxodium Ascendens*
Swamp Tupelo	*Nyssa Sylvatica Biflora*
China Berry	*Melia Azedarach*
Shrubs	
Blueberry	*Vaccinium Spp.*
Beauty Berry	*Callicarpa Americana*
Mulberry	*Morus Rubra*
Hawthorn	*Crataegus Spp.*
Sparkle Berry	*Vaccinium Arboreum*
Wax Myrtle	*Myrica Cerifera*
Winged Sumac	*Rhus Copallina*
Elderberry	*Sambucus Nigra*
Chinese Privet	*Ligustrum Sinense*
Pokeweed	*Phytolacca Americana*
Vines	
Blackberry	*Rubus* Spp.
Greenbrier	*Smilax* Spp.
Japanese Honeysuckle	*Lonicera Japonica*
Muscadine	*Vitis Rotundifolia*
Peppervine	*Ampeiopsis Arborea*
Poison Ivy	*Rhus Radicans*
Poison Oak	*R. Toxicodendron*
Rattan Vine	*Berchemia Scandens*
Trumpet Vine	*Campsis Radicans*
Virginia Creeper	*Parthenocissus Quinquefolia*
Yellow Jessamine	*Gelsemium Sempervirens*
Grasses	
Bahia	*Paspalum Notatum*
Broomsedge	*Andropogon* Sp.
Panic Grass	*Panicum* Sp.
Plume Grass	*Erianthus* Sp.
Switch Cane	*Arundinaria Tecta*
Knotgrass	*Paspalum Distichum*
Johnson Grass	*Sorghum Halepense*
Japanese Stilt Grass	*Microstegium Vimineum*

List of Referenced Species (with common name; plant nomenclature follows Radford et al. (1987) *(Continued)*

FORBS	
Begger Lice	*Desmodium Sp.*
Butterfly Pea	*Clitoria Mariana*
Dayflower	*Commelina Sp.*
False Dandelion	*Pyrrhopappus Carolinianus*
Fleabane	*Erigeron* Spp.
Golden Rod	*Salidago* Spp.
Camphorweed	*Heterotheca Subaxillaris*
Milkpea	*Galactia* Spp
Bean	*Fabaceae* Spp.
Pippsissawa	*Chimaphila Maculata*
Sedge	*Cyperus* Spp.
Sericea Lespedeza	*Lespedeza Cuneata*
Thistle	*Carduus* Spp.
Verbena	*Verbena* Sp.
Rattlebox	*Crotolaria* Sp.
Knotweed	*Scleranthus* Sp.
Dogfennel	*Eupatorium* Sp.
Common Mullein	*Verbascum Thapsus*
Meadow Beauty	*Rhexia Virginiana*
Sedge	*Carex* Sp.
Rush	*Scirpus* Sp.
LICHENS AND FERNS	
Chain Fern	*Woodwardia Areolata*
Spleenwort	*Asplenium Platyneuron*
BIRDS	
Acadian Flycatcher	*Empidonax Virescens*
American Crow	*Corvus Brachyrhynchos*
Barred Owl	*Strix Varia*
Blue-Gray Gnatcatcher	*Polioptila Caerulea*
Blue Jay	*Cyanocitta Cristata*
Northern Cardinal	*Richmondena-Cardinalis*
Carolina Chickadee	*Parus Carolinensis*
Carolina Wren	*Thryothorus Ludovicianus*
Chimney Swift	*Choetura Pelagica*
Downy Woodpecker	*Picoides Pubescens*
Eastern Kingbird	*Tyrannus Tyrannus*
Eastern Wild Turkey	*Meleagris Gallopavo*
Eastern Towhee	*Pipilo Erythrophthalmus*
Hairy Woodpecker	*Dendrocopus Villosus*
Indigo Bunting	*Passerina Cyanea*
Mississippi Kite	*Ictinia Mississippiensis*
Mourning Dove	*Zenaidura Macroura*
Northern Flicker	*Colaptes Auratus*
Pileated Woodpecker	*Dryocopus Pileatus*
Pine Warbler	*Dendroica Pinus*
Red-Eyed Vireo	*Vireo Olivaceus*
Red-Bellied Woodpecker	*Melanerpes Carolinus*
Summer Tanager	*Piranga Rubra*
Tufted Titmouse	*Baeolophus Bicolor*
White-Breasted Nuthatch	*Sitta Carolinensis*
White-Eyed Vireo	*Vireo Griseus*
Yellow-Billed Cuckoo	*Coccyzus Americanus*
Mammals	
Domestic Pig (Feral)	*Sus Scrofa*
White-Tail Deer	*Odocoileus Virginianus*

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FIGURES

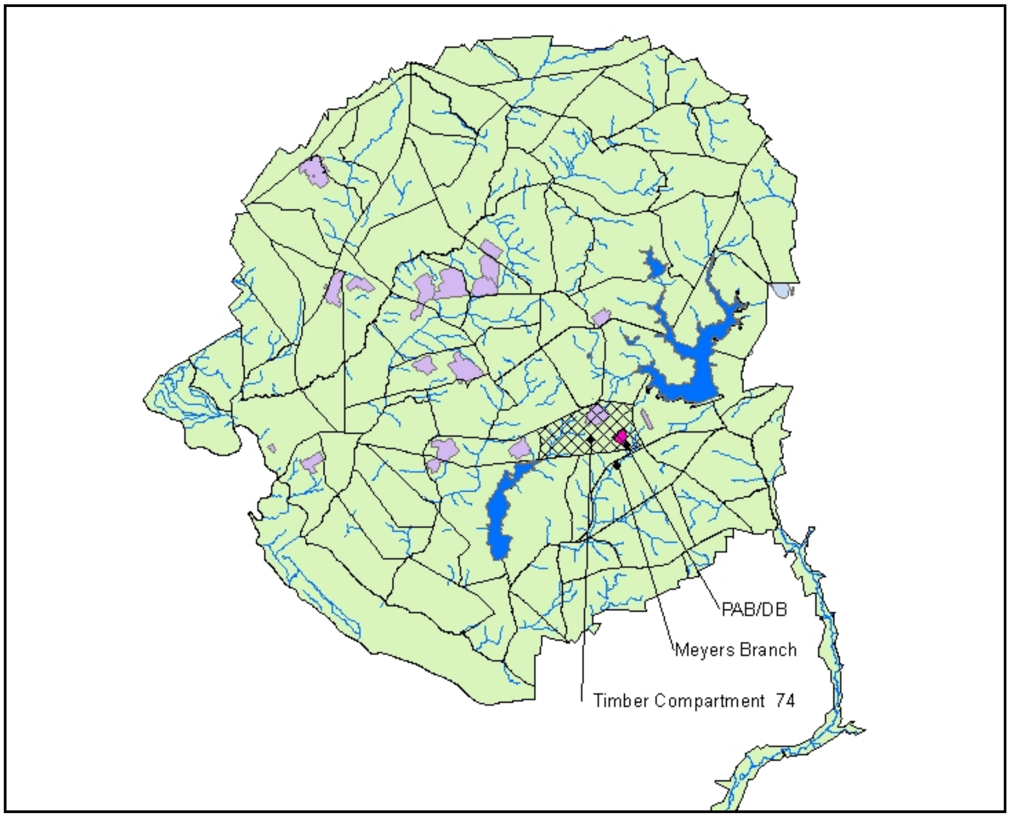

Figure 1. Location of the PAB/DB, Meyers Branch and Timber Compartment 74 Within the SRS

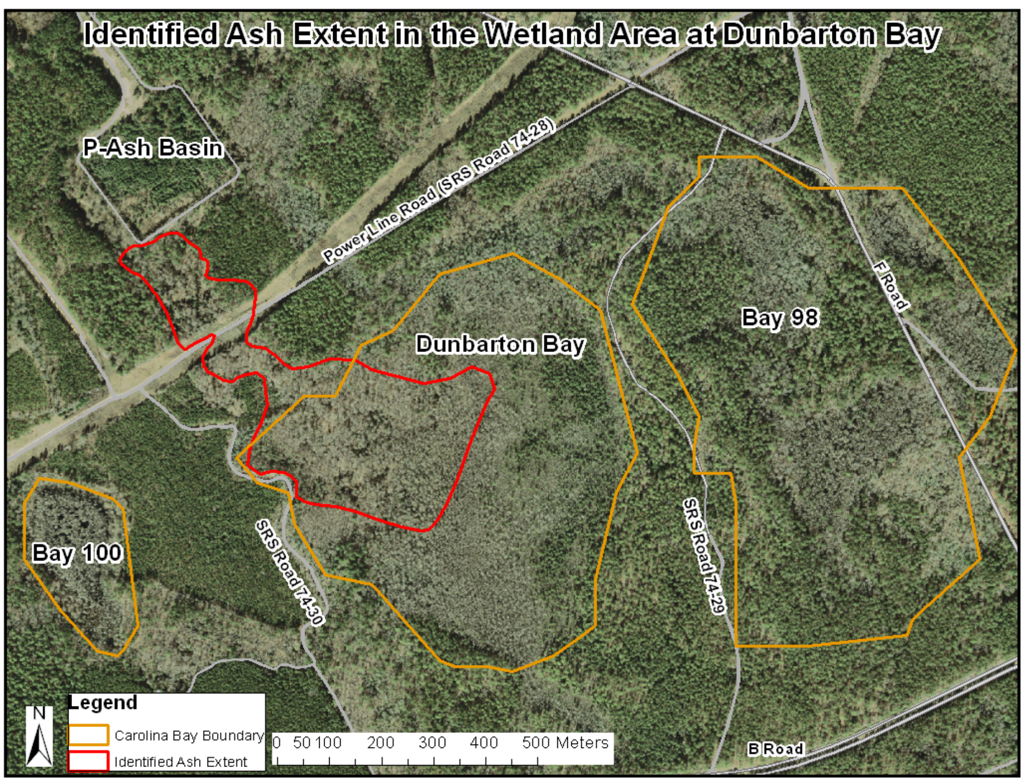

Figure 2. Location of PAB Showing Extent of Ash Deposits Downgradient and Within the DB Wetland (Photo Taken from SRNS, 2011)

Figure 3. SREL's Herpetofauna Monitoring Efforts in the Survey Using Urift Fences and Capture Buckets.

Figure 4. Disturbed Upland Mixed Pine/Hardwood and Scrub/Shrub Habitat Within the Impacted Area Immediately Downgradient of the PAB

Figure 5. Powerline (Ash Flow Road 74-28) ROW Habitat Within the Impacted Area Downgradient of the PAB

Figure 6. **Opened Understory Conditions in the Mixed Bottomland Hardwood Pine Habitat in the DB Downgradient of the PAB and ROW**

Figure 7. **Bottomland Hardwood Habitat Transitioning Into Cypress-Tupelo Swamp Within the Impacted DB**

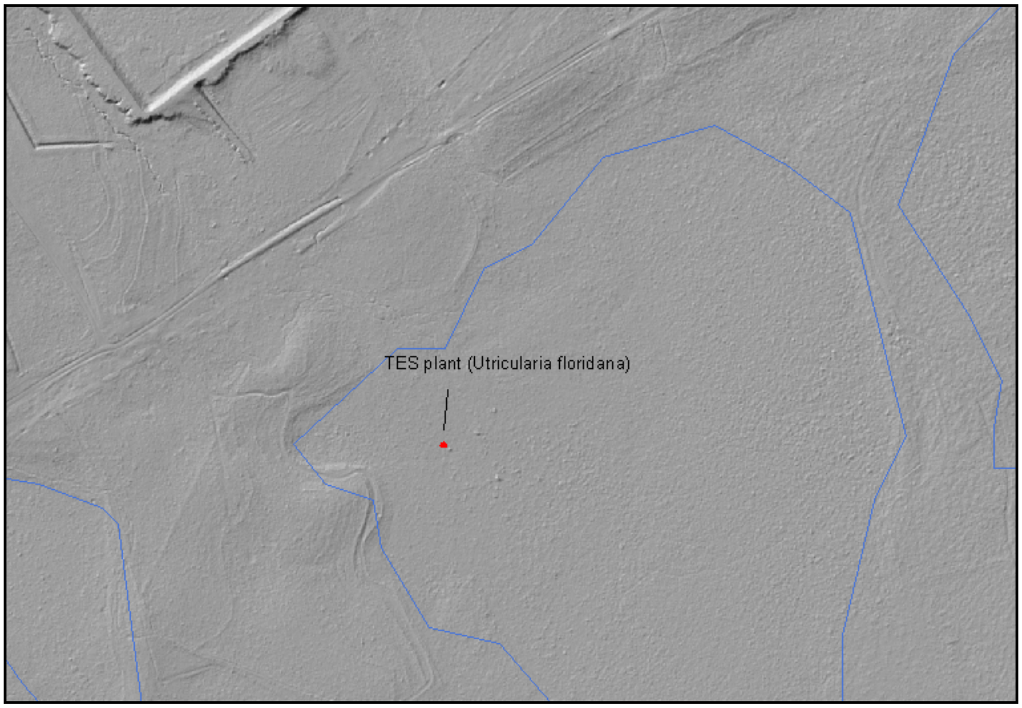

Figure 8. Previous Location of a Florida Bladderwort Population in the Survey Area

Figure 9. Evidence of White-Tailed Deer Reproductive Behavior in DB Impacted Area

Attachment C-2

P-Area Wetland Studies
Soils and Biota

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P-AREA WETLAND STUDIES

SOILS AND BIOTA

Final Project Report

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ABBREVIATIONS AND ACRONYMS

ACP	Area Completion Projects
CCW	Coal Combustion Wastes
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CMCOC	Contaminant Migration Constituent of Concern
CM	Contaminant Migration
COC	Constituents of Concern
COPC	Constituents of Potential Concern
DAPW	D-Area Ash Plume Wetland
DB	Dunbarton Bay
ECO	Ecological
EPA	Environmental Protection Agency
ft	Foot / feet
GIS	Geographic Information Systems
ha	Hectares
HH	Human Health
HQ	Hazard Quotient
ICP-AES	Inductively Coupled Plasma-Atomic Emission Spectrometry
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
ID	Inner Diameter
IOU	Integrator Operable Unit
LOD	Limit of Detection
M	Meter/meters
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
OM	Organic Matter
PAB	P-Area Ash Basin
PAPW	P-Area Ash Plume Wetland
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RSL	Regional Screening Level
SAP	Sampling and Analysis Plan
SCDHEC	South Carolina Department of Health and Environmental Control
SOPs	Standard Operating Procedures
SREL	Savannah River Ecology Laboratory
SRNS	Savannah River Nuclear Solutions, LLC
SRS	Savannah River Site
SVL	Snout-Vent Length
TAL	Target Analyte List
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
XRF	X-Ray Fluorescence

EXECUTIVE SUMMARY

The Savannah River Ecology Laboratory (SREL) has a strong research history on the ecological effects of contaminants on the Savannah River Site (SRS), including the effects of coal combustion wastes (CCW). Coal-fired facilities have been in operation on the SRS since the early 1950s and there are multiple associated ash basins, as well as areas of CCW spills. Acceptable clean-up and closure of CCW sites on the SRS requires knowledge of contaminant levels and quantification of the diversity and success of the biota inhabiting these areas.

Most SREL CCW research has focused on the D Area settling basins where contaminant levels are highest. Research in the settling basins demonstrated that amphibians and other wildlife inhabiting the basins and discharge streams can accumulate elevated concentrations of trace elements that cause adverse effects on survival, growth and development, energy acquisition and allocation, behavior or performance, and recruitment (reviewed in Rowe et al. 2002). However, potential impacts of CCW in other habitats, such as the ash plumes in D Area and P Area that extend into natural wetlands, are largely unknown. For example, a CCW release occurred more than 35 years ago at a portion of the D-Area Savannah River floodplain (D-Area Ash Plume Wetland, DAPW); currently the DAPW appears to have a normal amphibian community diversity (19 documented species, comparable to a nearby uncontaminated reference site; Roe et al. 2005), and the DAPW forest also exhibits species richness and basal area typical for a forest its age. Trace element concentrations in the floodplain surface soils are generally lower than in the more recent CCW of the settling basins (concentrations in tissue from several amphibian species are also lower compared to more recent CCW).

In this study we examined the distribution of trace elements in soils and biota at a portion of Dunbarton Bay (DB), a large wetland complex at the head of the Meyer's Branch valley on the SRS. Dunbarton Bay is down gradient from the P-Area Ash Basin, and an historic release of CCW deposited ash (up to 1 m) over approximately 18.2 ha in one of the smaller wetlands within DB known as Bay 96. [Note: On the SRS GIS wetlands layer, Bay 96 includes additional area that did not receive CCW. For the purposes of this report, we use Bay 96 synonymously with the CCW plume area of the wetland.] Bay 96 appears to function as a seasonal wetland, and may be similar in key respects to the DAPW. The makeup of CCW at the two sites may vary due to differences in parent coal composition, combustion technology, and disposal method. As a consequence, the CCW in the P Area system may differ from CCW deposits elsewhere on the SRS; it has not been established whether data from one basin can be applied to another. This report summarizes our findings from the P-Area system; we include limited data on the D-Area system for direct comparison.

Contaminants of potential concern (COPC) to aquatic receptor species have been identified in preliminary P Area wetland surveys and SRS ecological risk models. We determined COPC levels in soil cores and biota from the affected area of Bay 96, as well as from a nearby uncontaminated wetland reference site (Bay 100). Soil cores were collected from ten sampling locations, seven within the ash depositional area and three outside the ash deposition zone, as well as two additional background wetland sampling locations within Bay 100. The metal levels in the seven sites impacted by ash deposition were elevated when compared to the three sites outside the ash deposition zone and background metal concentration for SRS upland soils. In Bay 96 soils, the levels of arsenic (As), copper (Cu), nickel (Ni), selenium (Se), and strontium (Sr) were elevated relative to the reference wetland; lead (Pb) and mercury (Hg) were higher at Bay 100. Within Bay 96, the soil levels of As, barium (Ba), beryllium (Be), cadmium (Cd), cobalt (Co), Cu, Pb, Ni, Se, and zinc (Zn) were elevated for the ash-impacted sampling sites compared to the three non-ash-impacted sites. Although the two Bay 100 background soils display rather minor levels of As (≈ 1.1-1.7 mg kg^{-1}), a major contaminant found in CCW, they exceed "upland" soil background thresholds (i.e., 2 times the mean background value) for Ba, Be, Cu, Pb, Ni, and Zn. However, elevated trace element concentrations observed in Bay 100 compared to upland soils likely reflect the higher clay and organic matter (OM) contents observed in wetland soils.

Site remediation decisions require an assessment of the potential ecosystem-level risk of trace element contaminants to organisms, including: 1) a species list (biological survey) for the habitat of interest for comparison to reference sites, 2) species-specific estimates of trace element concentrations (body burdens), and 3) the measurement of endpoints that reflect the individual and population-level consequences of elevated trace element body burdens (population effects). In our study, we conducted biological surveys of Bay 96, Bay 100, and select D-Area sites for comparison, and determined trace element tissue concentrations in a variety of organisms. Given the time and funding constraints, we were not able to conduct extensive population demography studies or experimentally assess

chronic sub-lethal effects at the observed trace metal concentrations in Bay 96. Consequently, we are relying on prior experiments at CCW levels in the D Area system to speculate about potential CCW impacts on biota in P Area.

In general, the biota we examined at Bay 96 had elevated As, Se, and Sr tissue concentrations compared to animals from Bay 100. Despite these differences, concentrations in Bay 96 fauna were relatively low (e.g., As, 3-6 mg/kg dry mass; Se, 0.8-3 mg/kg) compared to those captured at the D-Area Primary Ash Settling Basin (As, 3-7 mg/kg; Se, 15-46 mg/kg) and D-Area Ash Plume Wetland (As, 1.6-3.4 mg/kg; Se, 6-22 mg/kg). Tissue concentrations were highly correlated with soil concentrations for As, Se, and Sr, and soil concentrations of these COPC were elevated in the D Area system compared to P-Area (Bay 96).

For amphibians, both the contaminated site (Bay 96) and the reference site (Bay 100) were similar in species richness and composition. Greater numbers of captures occurred at Bay 100, but we think this was primarily due to 1) the presence of water for portions of the sample period at Bay 100 but not at Bay 96, and 2) a difference in configuration of our sampling fences that were likely sampling animals during their breeding migration at Bay 100 but only resident animals at Bay 96. Thus, any population-level differences between the two sites were more likely due to between-site hydroperiod differences rather than any direct effects of elevated COPC at Bay 96.

Characterization of Contaminant Levels in the P-Area Wetland System

Soils: John Seaman and Julian Singer

Biota: David Scott, Larry Bryan, David Kling, and Stacey Lance

BACKGROUND & INTRODUCTION

Environmental contaminants come from many sources, but coal-fired plants are one of the largest producers of contaminated solid wastes in the U.S. (USDOE, 2005). Coal combustion wastes (CCW) contain high concentrations of trace elements [including arsenic (As), cadmium (Cd), selenium (Se), and strontium (Sr)] and are often disposed of in open aquatic settling basins (Rowe et al., 2002). Amphibians and other wildlife that use these basins can accumulate elevated concentrations of trace elements, which may result in adverse effects on survival, growth, development, behavior, performance, and recruitment (Hopkins et al., 2000, 2006; Raimondo and Rowe, 1998; Rowe et al., 1996). Some studies suggest that CCW contaminated wetlands may serve as ecological sinks to amphibian populations (Roe et al., 2006; Rowe and Hopkins, 2003; Snodgrass et al., 2003, 2004, 2005).

Coal-fired facilities have operated on the Savannah River Site (SRS) since the early 1950s. Seven coal plants associated with steam generation were once in use on the SRS, each with its own production history and associated CCW. Variation in CCW contaminant levels likely occurs across sites due to individual coal-plant history, source of the parent coal material, and natural attenuation of contaminants after facility shutdown. For example, at D-Area on the SRS, a contaminant concentration gradient occurs from very recently deposited CCW in the primary settling basin to >35-yr-old CCW deposited in a nearby wetland and floodplain. The D-Area Ash Plume Wetland (DAPW) received CCW through the early 1970s, resulting in a CCW plume that extends over 40 ha of floodplain at depths up to 2.7 m. The DAPW has not received CCW discharge for >35 years and the impacted area (including the wetland) has become revegetated with a mixed floodplain community and a thin organic soil layer has developed. High organic matter and low pH in the surface horizon of soil facilitates the release and downward transport of metals to lower horizons, where they may be immobilized (Sandhu and Mills, 1991). Thus, the bioavailability of metals may be reduced in aged sediments from historic CCW deposits where surface leaching has occurred.

In 2010, a surface plume of CCW was discovered to extend from the P-Area Ash Basin (PAB) into the Dunbarton Bay (DB) system, a Carolina Bay wetland (Sharitz 2003), with surface ash deposits within DB ranging up to 1 m (SRNS, 2011). The disposition of the PAB is being addressed within the P-Area Operable Unit, while the ash plume within the DB wetland system is being addressed as part of the Steel Creek Integrator Operable Unit (IOU). The CCW-affected area of DB is a wetland subunit known as Bay 96 on the SRS GIS wetlands layer.

A Preliminary Risk Assessment/Contaminant Migration Evaluation conducted using the limited soil and surface water data collected in 2010 indicated a broad distribution of contamination within DB (ERD-EN-2010-0084). The maximum reported soil concentrations for inorganic contaminants within the DB system are provided in Table 1, with a threshold of 2 times (2X) the average concentration for the same elements in non-impacted, upland soils on the SRS (i.e., background soil levels). The DB soil levels exceeded the 2X average background for 13 of the 18 elements reported in Table 1.

Based on the preliminary soil and surface water data, the Human Health (HH) risk assessment for an industrial worker identified As , a contaminant commonly found in CCW, as the primary inorganic hazardous constituent for soil media, while As and vanadium (V) were both elevated above surface water MCL thresholds. The ecological (ECO) assessment identified several contaminants of potential concern (COPC), including As, for benthic- dwelling and aquatic organisms, and mammalian aquatic predators. Additional ecological COPCs include aluminum (Al), barium (Ba), copper (Cu), iron (Fe), and manganese (Mn). The preliminary contaminant migration (CM) screening identified beryllium (Be) and thallium (Tl) as additional Contaminants of Concern (COC), in addition to several elements identified in the previous ECO assessment, i.e., As, Ba, and Fe.

Table1. Maximum Detected Soil Concentrations Reported For Preliminary Soil Samples Collected From The Dunbarton Bay System and 2 Times (2X) The Average Value For Background "Upland" Soils On The SRS

Element	Symbol	DB Max*	2X Mean**	Exceeds 2X Bkg
		mg/kg		
Aluminum	Al	6,970	10,493	no
Arsenic	As	33.6	4.28	yes
Barium	Ba	144	39.0	yes
Beryllium	Be	2.08	0.288	yes
Cadmium	Cd	0.22	0.483	no
Chromium	Cr	15.4	15.4	no
Cobalt	Co	7.6	1.55	yes
Copper	Cu	55.8	4.34	yes
Iron	Fe	14,200	12,720	yes
Lead	Pb	13.6	10.3	yes
Manganese	Mn	354	153	yes
Mercury	Hg	0.077	0.071	yes
Nickel	Ni	12.6	3.48	yes
Selenium	Se	5.44	2.99	yes
Silver	Ag	0.204	0.728	no
Thallium	Tl	3.67	3.12	yes
Vanadium	V	25.8	39.1	no
Zinc	Zn	55	9.47	yes
*ERD-EN-2010-0084				
**WSRC 2006				

Bay 96, which is a subunit of DB, appears to function as a seasonal wetland, and may be similar in key respects to the DAPW in D Area. The DAPW supports 19 species of amphibians and numerous invertebrate species. The bioaccumulation of trace elements in the D-Area system, as well as their biological effects, has been documented in recent years. In this study we investigated whether COPC are present in soils and biota of Bay 96. We also compared observed COPC levels to those in the well-characterized DAPW and the D-Area Primary Ash Settling Basin. Biotic sampling was coupled with the collection and analysis of soil cores to determine metal distribution throughout the soil column – soil texture in the D-Area deposits is a silty loam with low sand and gravel content (Sandhu and Mills, 1991). Preliminary observations (DS, JS) of the soil in the PAPW indicated a much coarser texture, which may affect trace element partitioning, leaching, and subsequent bioavailability.

Amphibians are ideally suited for examining contaminant uptake because they are important components of aquatic and terrestrial communities. In many systems amphibians are the most abundant vertebrates and because of their high biomass and conversion efficiencies (Burton & Likens 1975; Grayson et al. 2005) they are responsible for substantial transfer of energy through food webs (Beard et al. 2002). Consequently, if environmental contaminants negatively affect amphibian populations then the whole ecosystem can be impacted (Hopkins 2007).

OBJECTIVES

The toxicology of trace elements has been reviewed for many groups of organisms, but studies of amphibians are relatively recent and significant data gaps remain. The fate and effect of trace elements in amphibians depend on the specific element, environment, and organism, and are influenced also by elemental concentration, its bioavailability, the duration of exposure, and the life stage of the organism. An assessment of the potential ecosystem-level risk of trace element contaminants to organisms requires: 1) a species list (biological survey) for the habitat of interest, 2) species-specific estimates of trace element concentrations (body burdens), and 3) the measurement of endpoints that reflect the individual and population-level consequences of elevated trace element body burdens (population effects).

Our objectives in this study were to:

- Characterize the COPC levels in the physical environment by quantifying trace element concentrations in Bay 96 ash-impacted soils, Bay 96 soils outside the ash plume, and reference soils at Bay 100. This characterization includes changes in COPC concentrations throughout the soil profile (to ~1 m).
- Conduct a limited biological survey, focused primarily on amphibians, of Bay 96 and the reference site to establish a species list and document numbers of individuals.
- Estimate trace element concentrations in amphibians from the two sites, as well as COPC in a variety of amphibian prey items (ground beetles, ground spiders, millipedes, centipedes) and predators (small mammals such as shrews).
- Relate COPC concentrations in biota to levels in soil.

We sampled focal species and taxa in Bay 96 and Bay 100 to determine whole-body concentrations of As, Cu, Se, and V. Although Se was not identified as a COPC in preliminary risk assessments for P Area, it has been associated with significant effects in the DAPW studies. We also estimated levels of other elements [e.g., Cd, chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), Sr, and zinc (Zn)] that were typically reported in historical studies. These estimates are compared to levels documented in taxa in the DAPW, for which there is additional biological effects information. The COPC concentrations observed in Bay 96 organisms can be used to refine risk assessment estimates for aquatic and terrestrial receptor species (i.e., green heron, raccoon, shrew, robin; e.g., Paller et al. 2006).

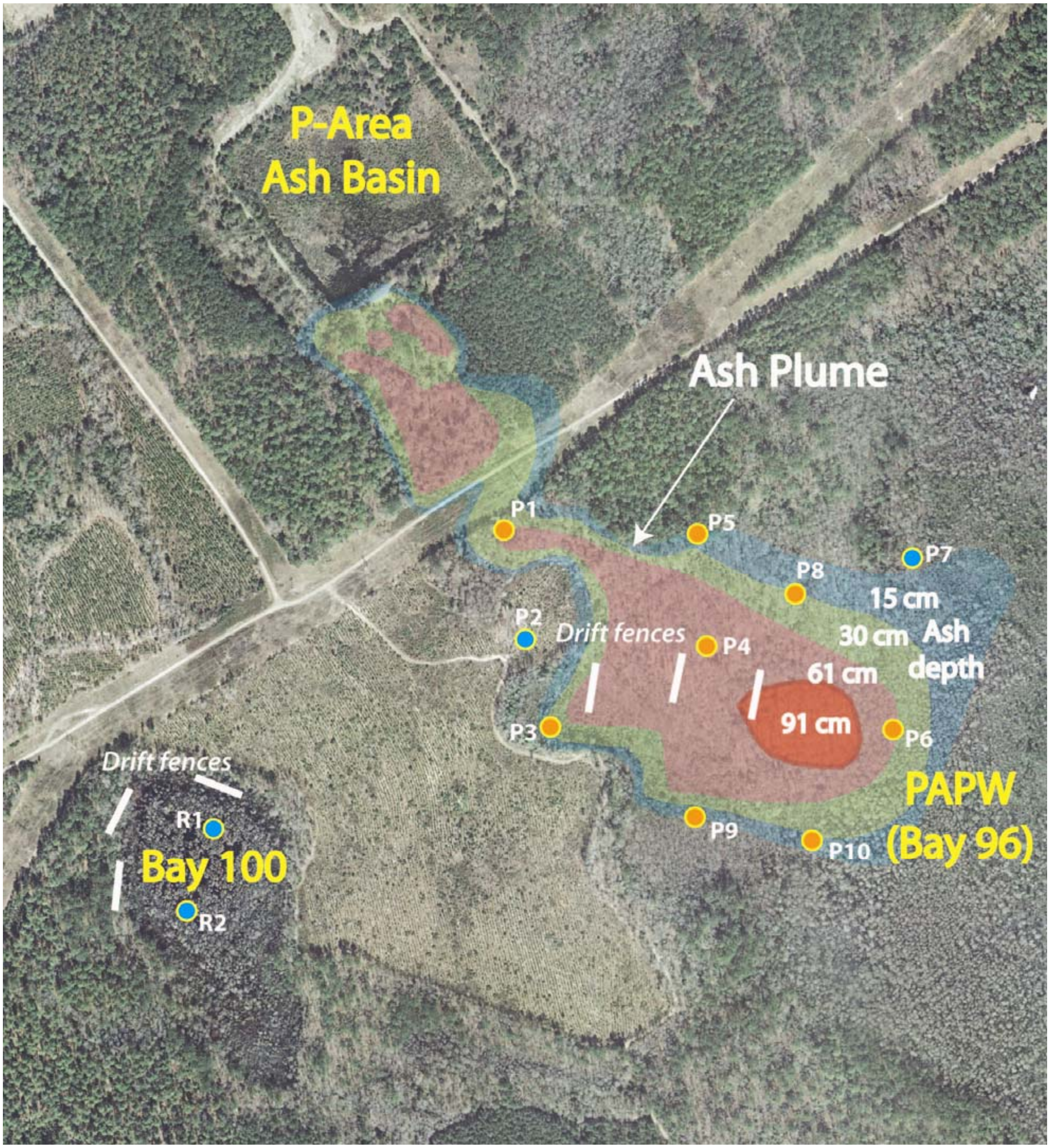

Figure 1. *Locations of sampling sites in the P-Area system. Portions of Bay 96 contain coal combustion wastes to a depth of ~91 cm; this ash plume is referred to as the P-Area Ash Plume Wetland (PAPW). Biota and soils sampled in Bay 96 were analyzed for metals and compared to samples from an uncontaminated reference site (Bay 100) located 315 m to the west. Sampling locations for biota (drift fences) and soil cores indicated as marked. Blue cores indicate sites where little or no evidence of ash was found.*

METHODS.

Soils.

In July and August of 2011, SREL collected a set of intact soil cores from 12 sampling locations within Bay 96 (Fig. 1) to determine if contaminant levels are above IOU benchmarks and contaminant migration (CM) screening values that warrant additional remedial action. Soil cores were collected from ten locations within and adjacent to the recently discovered ash plume derived from P-Area Ash Basin. Soil samples were also collected from two locations within Bay 100 near the DB system for use as suitable non-impacted background soils representing wetland conditions (Table 2). The exact sampling locations were determined in consultation with Area Closure Projects (ACP), and further documented using GPS. Soil sampling was restricted to a depth of ~ 1 m.

Initial soil sampling efforts were unsuccessful because of the inability to retain the friable, coarse-textured soil materials in the 5-cm ID sampling tube during extraction. Therefore, intact soil cores were collected using a smaller-diameter (2.3-cm ID), manual, slide-hammer coring device. Because of the small core diameter, at least two cores were collected at each sampling location. Poor soil recovery was noted at many of the sampling locations (Table 2). As demonstrated in Fig. 2 for sampling location 10, approximately 69.9 cm of soil core 10A was recovered while the full depth of sampling was 96.5 cm as determined by measuring the depth of the resulting hole after sampling. Even more dramatic, only 30.5 cm of soil was recovered for soil core 10B while the full depth of sampling was 94 cm. While sample compaction may account for some of the discrepancies between the recovered soil core length and the full depth of sampling, poor soil recovery was generally noted for sampling locations that offered little physical resistance to coring. This suggested the presence of subsurface voids, possibly resulting from the decay of dead tree roots.

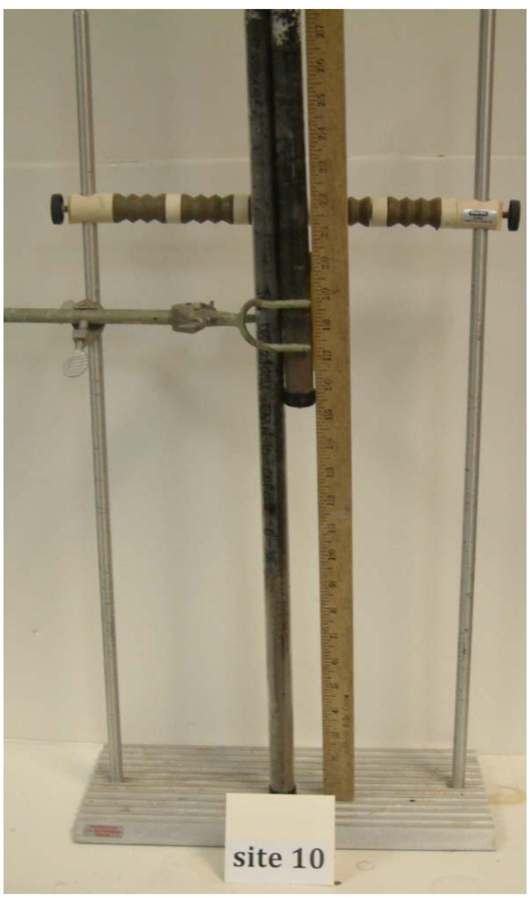

Figure 2. Intact Soil Cores A (l) and B (r) Collected from Site 10 in the Dunbarton Bay System

Table 2. Sampling Details for Soil Cores Collected within the P-Area System (Bays 96 and 100)

Site	Core Designation	North	West	Collection Date	Depth Interval	Core Recovery Length
	Degrees Minutes Seconds				cm*	cm
1	a	33° 13' 9.8"	81° 34' 19.9"	7/21/2011		83.8
	b			7/21/2011		91.4
2	a	33° 13' 5.5"	81° 34' 18.8"	7/27/2011	101.6	66.0
	b			7/27/2011	104.1	91.4
3	a	33° 13' 2.3"	81° 34' 17.5"	7/28/2011	121.9	53.3
	b			7/28/2011	106.7	49.5
4	a	33° 13' 4.3"	81° 34' 11.8"	8/18/2011	96.5	67.3
	b			8/18/2011	101.6	68.6
5	a	33° 13' 6.6"	81° 34' 9.3"	8/16/2011	91.4	62.2
	b			8/16/2011	88.9	53.3
6	a	33° 13' 4.0"	81° 34' 6.7"	8/16/2011	114.3	73.7
	b			8/16/2011	116.8	81.3
7	a	33° 13' 9.1"	81° 34' 3.8"	8/16/2011	96.5	80.0
	b			8/16/2011	109.2	81.3
8	a	33° 13' 9.6"	81° 34' 12.5"	8/16/2011	101.6	76.2
	b			8/16/2011	104.1	77.5
9	a	33° 12' 58.6"	81° 34' 12.7"	7/28/2011	71.1	45.7
	b			7/28/2011	121.9	33.0
	c			7/28/2011	91.4	73.7
	d			7/28/2011	88.9	69.9
10	a	33° 12' 57.9"	81° 34' 7.2"	8/12/2011	96.5	69.9
	b			8/12/2011	94.0	30.5
	c			8/12/2011	94.0	44.5
Dunbarton Bay 100 Control Sites						
1	a	33° 12' 59.2"	81° 34' 32.7"	8/1/2011	101.6	99.1
	b			8/1/2011	106.7	91.4
2	a	33° 12' 57.2"	81° 34' 33.5"	8/1/2011	116.8	61.0
	b			8/1/2011	86.4	58.4
*Based on the depth of the resulting hole after sampling.						
**Depth span in recovered soil core.						

After sampling, the intact cores were transported to the lab and photographed for archiving purposes. The core tubes were then sliced open, and carefully placed in PVC channels for visual examination, noting soil horizonation and obvious ash deposition layers. Initial visual characterization indicated that 3 of the 10 sampling locations (Sites 2, 7 and 8) were outside the zone of CCW deposition, as can be seen by comparing soil cores from sampling sites 2 and 9 (Fig. 3). Discrete subsamples were collected representing obvious soil horizons from each individual soil core, and analyzed by X-ray fluorescence (XRF) to evaluate the vertical distribution of ash-derived contaminants present in each intact soil core (Kalnicky and Singhvi, 2001; USEPA, 1998).

In accordance with standard soil screening practices, a bulk sample representing the upper 30 cm (~1 ft) of soil/ash materials, hereafter known as the surface soil layer, was collected for analysis of COCs. The representative surface layer samples from multiple cores collected at the same sampling location were combined to create one bulk sample per sampling location. When a significant detritus layer was present on the soil surface, it was removed before sampling to create the bulk surface soil material for subsequent chemical analysis. Prior to chemical analysis, the bulk surface soil samples were sieved to remove all material >2 mm. The samples were acid digested using EPA Method 3051A (USEPA, 2007a), and then analyzed for inorganic COCs by inductively coupled plasma-mass spectrometry (ICP-MS; NexION, Perkin Elmer, Inc.) and ICP-atomic emission spectrometry (ICP-AES; Optima DV 430-0, Perkin Elmer, Inc.) following the QA/QC protocols outlined in EPA Methods 6020A and 6010C, respectively (USEPA, 2007a; USEPA, 2007b; USEPA, 2007c). The surface soil samples were analyzed for Hg by EPA Method 7473 (USEPA, 2007d). The pH for the bulk surface soil samples was determined both in deionized water and 1 M KCl. The particle size distribution was determined using the micro-pipette method (Miller and Miller, 1987).

In addition, each bulk surface layer sample was extracted using the standard Toxicity Characteristic Leaching Procedure (TCLP; (USEPA, 1992), with the extracts analyzed by ICP-MS as described above, i.e., Method 6020A. TCLP extraction has been commonly used to estimate CM potential (Davis et al., 1990). The remaining soil materials were archived for additional physicochemical characterization as warranted.

A. P-Area Site 2

B. P-Area Site 9

Figure 3. Soil Samples Collected from Site 2 (A) and Site (9) Within Bay 96

Two replicate surface (1-15 cm) soil samples were also collected at each drift fence location (see below). These samples were used to determine soil texture and trace element concentrations at the locations where animals were captured, including the additional sites in D-Area. These samples allowed us to correlate trace element concentrations in soils to concentrations in organisms from the same locale.

Biota.

We monitored biota at Bay 96 and the reference site (Bay 100) from April to October 2011. Bay 100 is a 5.1-ha isolated wetland with no known history of contamination located approximately 315 m west of Bay96. We also conducted limited concurrent sampling at the D-Area Primary Settling Basin and the DAPW for direct comparison to the P-Area results.

We used standard amphibian capture and processing techniques (Heyer et al. 1994) at Bay 96 and Bay 100 to collect samples from target taxonomic groups for trace element analyses. In March 2011 we installed three 30-m long drift fences with paired pitfall traps at both P-Area sites. Fences at Bay 96 were placed within the known ash plume, and fences at Bay 100 were installed around the margin of the wetland (Figure 1). Fence location at Bay 96 increased the likelihood that captured animals were inhabiting the ash-impacted area, whereas fences at Bay 100 primarily captured amphibians migrating to and from the breeding site; thus, number of captures between the two locations may not be comparable. Sample collection extended from April to October 2011. Fences were checked three times per week from April-July, closed for August when no amphibian activity was occurring, and re-opened from mid-September until 31 October. Individuals of three species (the marbled salamander, *Ambystoma opacum*; southern toad, *Bufo terrestris*; spadefoot toad, *Scaphiopus holbrookii*) were marked by toe-clipping according to fence location to examine within and between site movements.

We collected target species of amphibians, reptiles, small mammals, insects, spiders, millipedes, and centipedes for metal analysis. For each taxon we determined mean trace element concentrations for the most abundant species, with a target of 10 samples per species per location. We compared trace element levels in the P Area system to levels observed in the same taxa in the DAPW, for which there is additional biological effects information.

To determine whole-body concentrations of metals, field-collected individuals were returned to the laboratory, euthanized with MS-222, weighed (± 0.01 g) and measured (± 0.5 mm), and frozen at -70°C until analysis. At a later date we thawed samples, rinsed them 2-3 times in deionized water, lyophilized them to constant mass, recorded dry mass, and homogenized each sample with a mechanical grinder. Grinders were cleaned with deionized water and 10% nitric acid between samples to eliminate cross contamination. Dried samples (approximately 150-250 mg of homogenized whole organism) were digested and analyzed for metal concentrations according to the following procedures (modified USEPA Methods 3052 and 6020A). We added trace metal grade nitric acid (10 mL) to samples before digestion in a microwave (CEM Corp., Matthews, NC) with heating steps of 60, 60, 70, and 80 percent microwave power for 10, 10, 15, and 20 minutes, respectively. We digested samples in batches of 40, including sample replicates, reagent blanks, and certified standard reference materials [Tort-2 (lobster hepatopancreas), NRCC, Ottawa, Canada]. After HNO_3 microwave digestion, we brought samples to a final volume of 15 mL with 18 MΩ deionized water and performed elemental analysis using ICP-MS (Elan DRC Plus, Perkin-Elmer Sciex Instruments, Toronto, Canada). Samples were diluted 1:1 with double deionized water, and calibration standards covering a range of 1-500 µg/L were prepared daily by serial dilution of NIST traceable primary standards. Statistical analyses were conducted using SAS v9.2.

RESULTS

Soil Cores and Elemental Analyses.

The extraction and pH results for the bulk surface soil layers are provided in Table 3. The soils can be divided into three subgroups: (a) ash-impacted soils from within Bay 96, (b) Bay 96 soils outside the ash deposition zone, and (c) background wetland soils collected from within Bay 100. As noted above, Sites 2, 7 and 8 were outside the zone impacted by ash deposition, and generally displayed lower levels for the COCs than observed for the ash-impacted soils, and in some cases even lower than background soils from within Bay 100. For comparison, the background metal concentrations for non-impacted upland and wetland soils on the SRS are provided in Table 4. A threshold of 2 times (2X) the average background value was chosen as an indicator of potential soil contamination, consistent with the preliminary risk assessment. The maximum reported background concentration for upland soils was also provided for comparison.

Characteristics of upland and wetland soils from the SRS may be quite similar as they are generally derived from the same parent materials, with differences arising from the unique weathering environments associated with their position on the landscape. Additionally, differences between upland and wetland soils cans be ascribed to differences in organic matter (OM) content and soil texture. Wetland soils generally contain higher levels of OM and clay, which can lead to naturally higher levels of trace elements when compared to coarse-textured upland soils. Therefore, additional metals concentration data for non-impacted wetland soils on the SRS are also provided in Table 4. Dixon (1997) divided wetland soils into five categories, one of which included upland bays and depressions (Dixon, 1997; Dixon et al., 1996), the category most analogous to the DB system currently under evaluation. However, the summary of Dixon (1997) reported in Table 4 reflects the entire wetland soil database. Average background values for several of the current COCs were not reported when less than 50% of the available analyses exceeded the analytical limit of detection (LOD) for the constituent under consideration. The limited data do suggest that the background levels for Ba, Be, Co, Cu, and Zn are generally higher for wetland compared to upland soils on the SRS. In general, Soil 1 displayed the highest levels for most metals, in many cases somewhat higher than the reported soil maximum for the ash-impacted soils collected for the preliminary risk assessment (see Table 2). All seven ash impacted soils exceed the 2X background soil threshold for 7 of the 18 constituents in Table 2 (i.e., As, Ba, Be, Co, Cu, Ni, and Zn), while the concentrations in samples from sites 2, 7 and 8 were generally below the 2X threshold for all metals tested. Although the two Bay 100 background soils display rather minor levels of As (~ 1.1-1.7 mg kg^{-1}), they exceed the 2X upland soil threshold for Ba, Be, Cu, Pb, Ni, and Zn. However, the values are in some cases less than the maximum reported values for upland soils (WSRC, 2006), and consistently less than the maximum reported values for background wetland soils (Dixon, 1997; Dixon et al., 1996). This suggests that the metal levels observed for the Bay 100 soil cores, although elevated when compared to coarse-textured upland soils, are within the natural range for the finer-textured, non-impacted wetland soils. Soil concentrations of V, Cr, Ni, Cu, Zn, Pb, U, Be, Mn, Ba, and Hg did not differ between the Bay 96 ash-impacted cores and Bay 100 cores. Five trace elements, As, Sr, Fe, Co, and Tl had higher concentrations ($F_{1,8} > 5.6$, $P < 0.05$) in the Bay 96 ash-impacted cores than at Bay 100; one trace element (Al) was higher ($F_{1,8} = 18.9$, $P < 0.05$) in Bay 100 sediments (Table 3).

The results for Al, Fe and Mn are quite variable between the three soil groups, and should be viewed with caution as these elements are important components of soil minerals that may not be fully extracted using the accepted the EPA method. Incomplete soil digestion combined with natural differences in soil texture and clay mineralogy likely control variability in major element compositions.

The TCLP extraction results are summarized in Table 5 along with the maximum threshold concentrations for inorganic contaminants. Data for other potential SRS operations-based contaminants (i.e., Co, and Ni) that lack a TCLP regulatory benchmark are also provided. The TCLP extractable contaminant levels for all ash-impacted soils are well below the regulatory threshold for all of the inorganic contaminants, and show no clear trends of enrichment within the ash deposition zone.

Table 3. Soil Digestion Results (EPA Method 3051A) For The Upper 30 Cm of Soil. Highlighted Sites (2, 6, And 7) Appear To Be Outside The Ash Deposition Zone

Site	Depth Interval				Be	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se
	cm	pH_w	pH_{KCl}*	Clay**						mg/kg[#]						
1	0-30	4.85	4.17	2.6	5.28	18,461	57.6	28.3	112.8	20,025	6.93	29.6	102.1	78.5	40.9	7.84
2	0-30	5.43	4.60	3.1	0.05	3,312	3.0	2.3	44.0	1,665	0.49	1.1	0.9	2.0	0.6	0.33
3	5-35	4.81	4.13	2.1	2.83	9,100	28.7	13.2	37.1	7,288	4.75	13.4	29.2	30.4	24.0	4.80
4	3.75-33.75	5.22	4.49	1.4	1.68	7,853	17.2	7.8	53.1	12,102	3.69	8.8	18.6	19.7	13.7	2.77
5	0-30	4.92	4.19	2.5	3.46	11,694	39.4	19.0	133.5	10,552	6.37	21.8	73.3	52.4	31.5	8.39
6	5-35	5.31	4.51	2.1	2.64	11,691	27.4	9.8	43.7	10,781	5.40	11.6	22.6	27.4	9.9	3.77
7	5-35	4.58	4.24	7.8	0.08	4,276	2.3	2.2	1.9	325	0.16	<MDL	0.7	<MDL	0.3	<MDL
8	0-30	5.02	4.40	6.9	0.10	6,704	7.6	4.1	111.0	3,894	0.82	2.0	2.4	4.4	1.1	0.28
9 (1)	2.5-32.5	4.67	4.11	3.9	1.11	7,596	11.1	6.2	25.6	9,026	2.17	4.8	12.9	19.5	26.8	1.69
9 (2)	2.5-32.5	4.74	4.12	3.3	3.55	10,516	39.5	20.5	66.5	10,682	5.72	20.0	50.0	53.7	23.1	4.81
10	0-30	5.30	4.85	3	2.16	6,119	18.7	10.1	113.8	4,563	4.55	12.1	25.3	27.9	11.9	3.75
Dunbarton Bay 100 Control Sites																
1	0-30	4.74	4.32	8.1	1.07	26,073	24.7	16.2	48.4	2,970	0.99	12.3	36.4	27.6	1.7	2.71
2	0-30	4.33	4.10	8.3	0.90	20,882	21.9	12.5	29.0	1,810	0.91	8.4	27.1	17.4	1.1	1.14
	MDL											0.89		1.20	0.29	0.2

Site	Depth Interval	Ag	Cd	Ba	Tl	Hg[##]	Pb
		mg/kg#					
1	0-30	<MDL	0.245	294.54	1.38	0.170	40.4
2	0-30	0.65	0.036	17.20	0.04	0.005	8.4
3	5-35	1.09781	0.167	171	1.03	0.075	15.5
4	3.75-33.75	<MDL	0.051	95.3	0.33	0.033	8.9
5	0-30	<MDL	0.249	163	1.30	0.116	28.8
6	5-35	<MDL	0.087	150	0.57	0.045	9.5
7	5-35	<MDL	<MDL	3.64	0.02	0.010	7.5
8	0-30	2.42	<MDL	20.2	0.06	0.009	8.4
9 (1)	2.5-32.5	<MDL	0.086	64.0	0.36	0.028	13.6
9 (2)	2.5-32.5	0.26417	0.187	170	1.43	0.062	29.9
10	0-30	<MDL	0.173	116	0.73	0.059	18.1
Dunbarton Bay 100 Control Sites							
1	0-30	<MDL	0.230	139	0.13	0.020	17.8
2	0-30	<MDL	0.236	145	0.07	0.027	17.5
	MDL	0.22	0.018				

*pH in 1 M KCl
**Miller and Miller (1987) micro-pipette method
[#]Metals extracted by EPA Method 3051A.
[##]Hg analyzed by EPA method 7473

Depth Interval – When present, the organic detritus layer was removed and only the mineral soil was sampled for testing.
MDL – Method Detection Limit

Table 4. Background Metal Concentrations For Upland And Wetland Soils On The SRS (Dixon, 1997; Dixon et al., 1996; WSRC, 2006)

		Upland Soils*				Wetalnd Soils**				
		Maximum	Mean***	2X Mean		Maximum	Median	Minimum	Mean****	2X Mean
Element	Symbol	mg/kg				mg/kg				
Aluminum	Al	19,200	5,247	10,493		52,050	3,745	65.6	7,019	14,039
Arsenic	As	23.80	2.140	4.28		5.99	0.124	0.011		
Barium	Ba	68	19.50	39.0		1,840	13.6	0.200	46.1	92.1
Beryllium	Be	0.48	0.144	0.288		4.66	0.163	0.025	0.511	1.02
Cadmium	Cd	2.01	0.242	0.483		4.20	0.0128	0.008		
Chromium	Cr	33.7	7.721	15.4		100	6.27	0.158	10.9	21.8
Cobalt	Co	3.74	0.775	1.55		49.9	0.528	0.093	2.24	4.49
Copper	Cu		2.171	4.34		39.2	1.94	0.102	4.50	8.99
Iron	Fe	25,000	6,360	12,720		52,000	637	12.3	4,364	8,728
Lead	Pb	18.7	5.149	10.3		48.9	3.63	0.109	6.48	13.0
Manganese	Mn	463	76.4	153		2,530	4.33	0.112	49.82	99.6
Mercury	Hg	0.30	0.036	0.071		0.30	0.0357	0.012		
Nickel	Ni	12.5	1.74	3.48		32.1	0.67	0.344		
Selenium	Se	5.2	1.50	2.99		13.0	0.124	0.077		
Silver	Ag	1.88	0.364	0.728		10.0	0.189	0.085		
Thallium	Tl	7.28	1.56	3.12		1.90	0.114	0.054	0.161	0.323
Vanadium	V	66.8	19.5	39.1		144	5.90	0.094	18.7	37.5
Zinc	Zn	19.8	4.74	9.47		100	4.26	0.127	11.8	23.6

*WSRC 2006; values represent the 0 to 1.0 ft sampling interval
**Dixon et al., 1996; Dixon 1997
***Calculated mean includes 0.5 x MDL for non-detect analytical values
****Means calculated only when >50% of samples reported values above LOD

Table 5. TCLP Extraction (EPA Method 1311; 40 CFR Part 261) Results For The Upper 30 Cm (USEPA, 1992). Highlighted Sites Appear To Be Outside The Ash Deposition Zone

Site	Depth Interval	As	Ba	Cd	Cr	Pb	Hg*	Se	Ag	Co	Ni
	cm				mg/L					mg/L	
1	0-30	<0.01	0.26	<0.01	<0.025	<0.01	<0.01	<0.01	<0.01	<0.01	0.04
2	0-30	<0.01	0.06	<0.01	<0.025	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
3	5-35	<0.01	0.28	<0.01	<0.025	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
4	3.75-33.75	<0.01	0.20	<0.01	<0.025	<0.01	<0.01	0.02	<0.01	<0.01	0.02
5	0-30	<0.01	0.23	<0.01	<0.025	<0.01	<0.01	0.03	<0.01	<0.01	0.04
6	5-35	<0.01	0.32	<0.01	<0.025	<0.01	<0.01	0.02	<0.01	<0.01	0.02
7	5-35	<0.01	0.06	<0.01	<0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
8	0-30	<0.01	0.08	<0.01	<0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
9	2.5-32.5	<0.01	0.24	<0.01	<0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
10	0-30	<0.01	0.19	<0.01	<0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dunbarton Bay 100 Control Sites											
1	0-30	<0.01	0.65	<0.01	<0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2	0-30	<0.01	0.56	<0.01	<0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TCLP Reg. Threshold		**As**	**Ba**	**Cd**	**Cr**	**Pb**	**Hg**	**Se**	**Ag**	**Co**	**Ni**
					mg/L					**mg/L**	
		5.0	**100**	**1.0**	**5.0**	**5.0**	**0.2**	**1.0**	**5.0**	NA	NA
NA - Not Applicable											
*Hg analyzed by EPA method 7473											

Biota and Whole-Body Concentrations

Seven species of amphibians and six species of reptiles were found at Bay 96; comparable numbers (eight amphibian species, six reptile species; Table 6) were observed at the reference site. We recorded 145 amphibian captures at Bay 96, and 334 amphibian captures at Bay 100; the southern toad (*Bufo terrestris*) was the most common species at both wetlands. For the three species in which we marked individuals by toe-clipping, we observed movement among fences within each location, but saw no movement between the two sites. Mean body size for *Bufo*, *Scaphiopus*, and *A. opacum* did not differ between sites (*Bufo*: $F_{1,137} = 0.91$, $P = 0.3412$; *Scaphiopus*: $F_{1,8} = 0.01$, $P = 0.9729$; *A. opacum*: $F_{1,7} = 0.48$, $P = 0.5179$).

Averaged across taxa (i.e., lumping all samples from each location together), there are significant location differences (Fig. 4) between tissue whole-body concentrations [multivariate analysis of variance test (MANOVA); $\lambda = 0.458$, $F_{11,102} = 10.99$, $P < 0.0001$]. The univariate tests showed that location differences were due to significantly elevated As, Se, Sr at Bay 96, and elevated Hg and Pb at Bay 100. Se and Sr were more than twice as high at Bay 96 compared to Bay 100 (Fig. 4). Taxonomic groups also appear to differ in their bioaccumulation patterns of certain elements (Fig. 5).

Comparison to D-Area

Trace element concentrations in soils at the fence locations varied widely across the CCW gradient from P Area to D Area (Fig. 6a and 6b). Within P-Area, Bay 96 surface soil metal concentrations at the drift fences were elevated ($P < 0.05$) in V, Cr, Ni, Cu, Zn, As, and Sr compared to Bay 100. Bay 100 surface soil concentrations at fences were elevated in Pb compared to Bay 96 soil. The P Area sites did not differ in Se and Hg; Cd levels were below detection limits. Bay 96 soil concentrations were generally lower than levels at ash-impacted sites in D Area, but higher than levels at the D-Area reference site (Fig. 6a and 6b). However, there were exceptions to this general pattern. Most notably, Cu and Zn levels were as elevated at Bay 96 as at D-Area ash sites, and Pb was lower at Bay 96 than at the two reference D Area soils in the Ash Basin (Primary Settling Basin) and the DAPW, trace metal levels in the wetlands. Soil concentrations of As, Se, and Sr showed consistent, positive correlations with tissue concentrations in several taxa (Table 2; Fig. 7). Vanadium was positively related to soil V levels only in amphibians. Species groups also differed in tissue trace element concentrations between P Area and D Area (Fig. 8).

Table 6. Amphibian and Reptile Species List for Bay 96 and Bay 100 (Apr 27 - Oct 30, 2011)

Bufo terrestris (southern toad), the most common species at both sites

Scaphiopus holbrookii (spadefoot toad), inhabits uplands at both wetlands

Species	PAPW	Bay 100
Amphibians		
Ambystoma opacum	X	X
A. talpoideum		X
Bufo terrestris	X	X
Gastrophryne carolinensis	X	X
Plethodon glutinosus	X	X
Rana clamitans	X	X
R. sphenocephala	X	X
Scaphiopus holbrookii	X	X
Reptiles		
Anolis carolinensis	X	
Coluber constrictor	X	X
Diadophis punctatus	X	
Eumeces fasciatus	X	X
Lampropeltis getulus		X
Sceloporus undulatus		X
Scincella laterale	X	X
Storeria dekayi	X	
Virginia valeriae		X

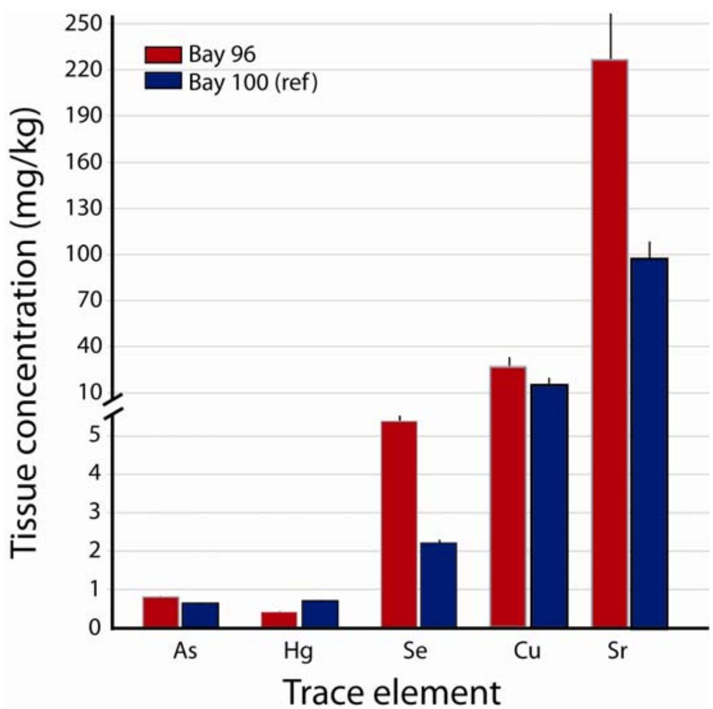

Figure 4. ***Metal Concentrations In Biota From Bay 96 and Bay 100. In General, Metal Concentrations Were Higher In Animals, Such As* Peromyscus *(Below), From Bay 96***

DISCUSSION

Determining whether low-level chronic exposure to contaminants affects population viability is a major challenge in ecotoxicology. Amphibians are ideally suited for examining contaminant effects because they are important components of aquatic and terrestrial communities, and often are sensitive to environmental contaminants. In particular, their permeable skin and susceptibility in both aquatic and terrestrial habitats puts them at high risk. Amphibians have been the subjects of numerous ecotoxicology studies (reviewed in Linder et al. 2003 and Sparling et al. 2000). Exposure to metals found in fly ash can have a range of effects including decreased survivorship of frog (Baud & Beck 2005; Rowe et al. 2001) and salamander (Horne & Dunson 1995; Roe et al. 2006) larvae, increased time to metamorphosis (James et al. 2005; Roe et al. 2006), and decreased size at metamorphosis (Peterson et al. 2009). An effect on body size at metamorphosis is critical because it affects adult fitness traits such as age at first reproduction, survival, and fecundity (Semlitsch et al. 1988; Scott 1994). Similarly, a contaminant-induced delay in metamorphosis may result in catastrophic mortality in a drying pond (Semlitsch et al. 1996). Ultimately, assessment of population-level effects requires knowledge of biological effects beyond measurements of contaminant body burdens.

Ground spider

Millipede

Scaphiopus holbrookii

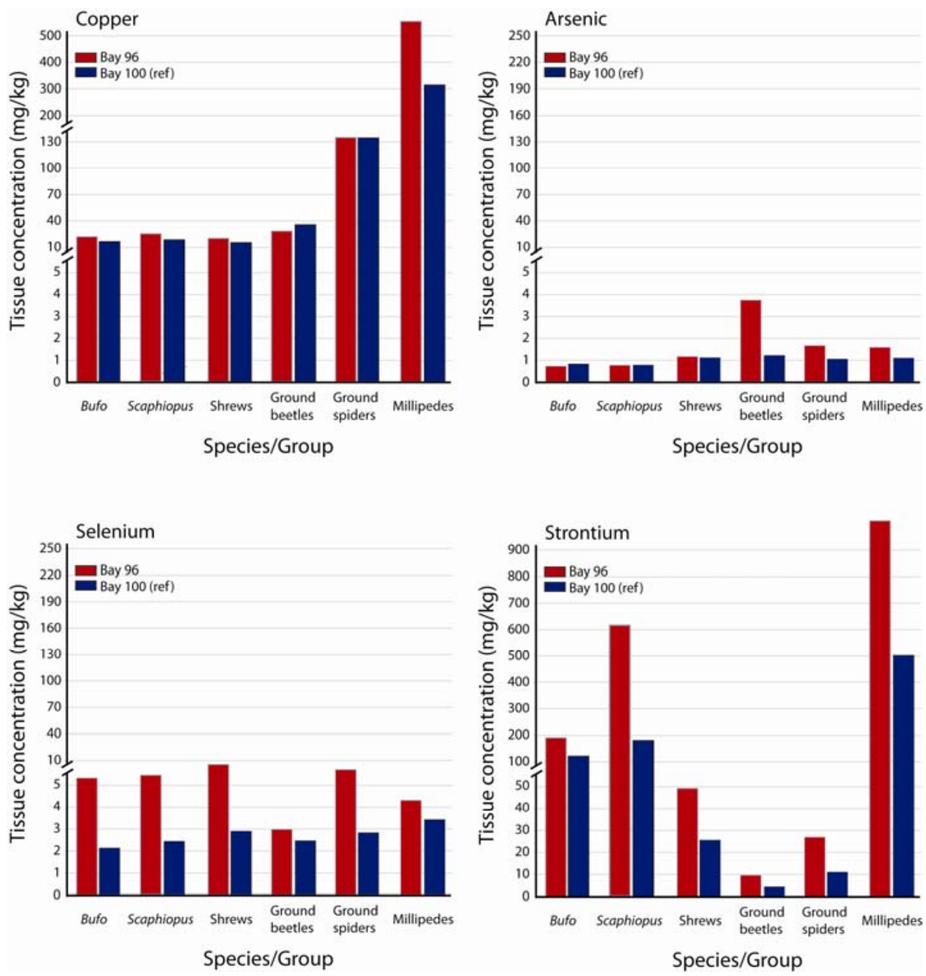

Figure 5. Metal Concentrations (Cu, As, Se, and Sr) in Biota from Bay 96 and Bay 100. Body Burdens Depended On Site, Metal, and Species/Group

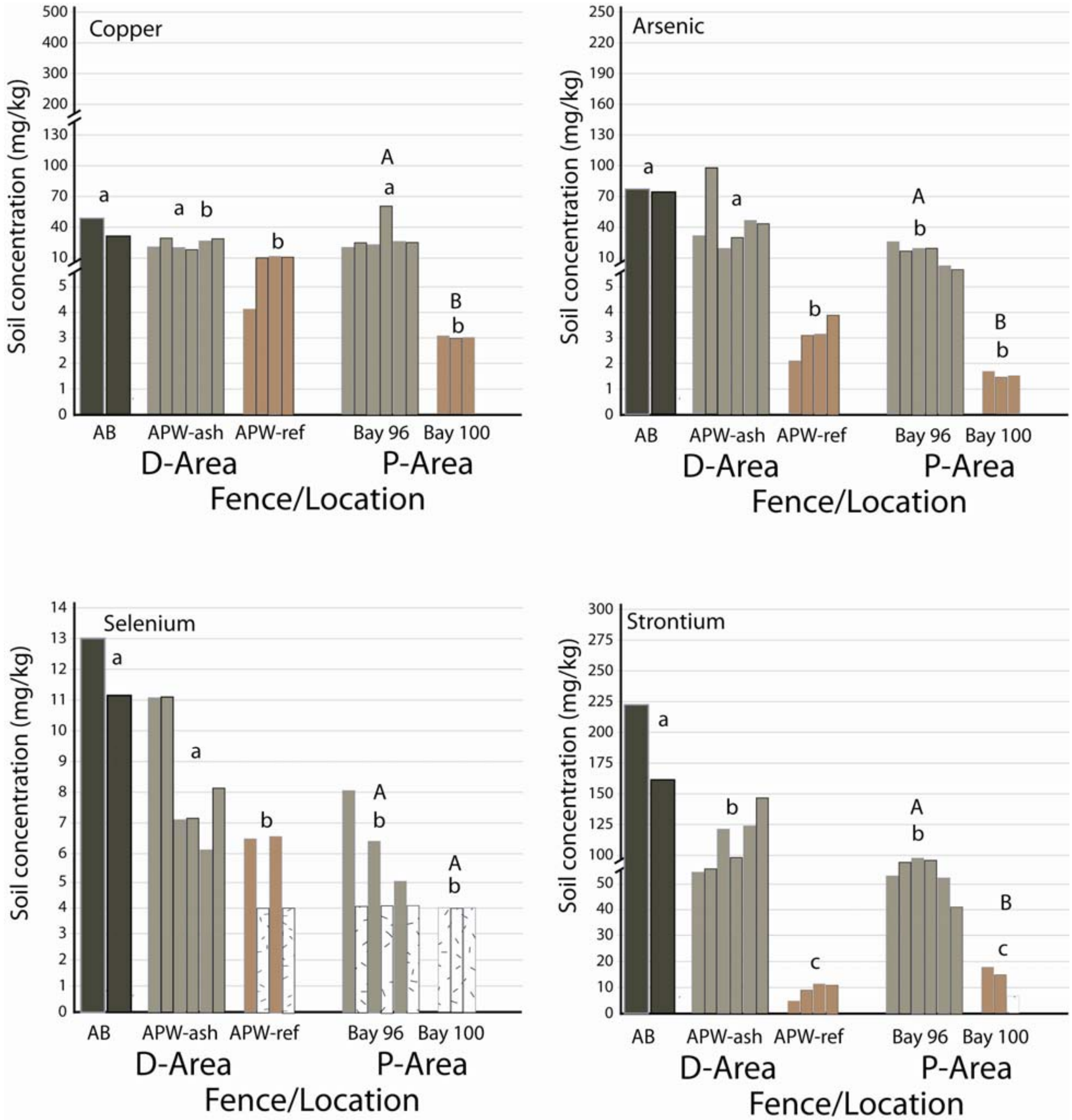

Figure 6a. Trace Element Concentrations in Surface Soil (1-15 Cm) From Each Drift Fence Location At Sample Sites In P Area and D Area (AB=Primary Ash Settling Basin, APW-Ash=Ash Plume Wetland With Ash Deposits, APW-Ref=Ash Plume Wetland With No Ash). Significant Differences Within The P-Area Sites Indicated By Upper Case Letters; Across All Sites Indicated By Lower Case. Hatched Bars Indicate Sample Values S Below MDL

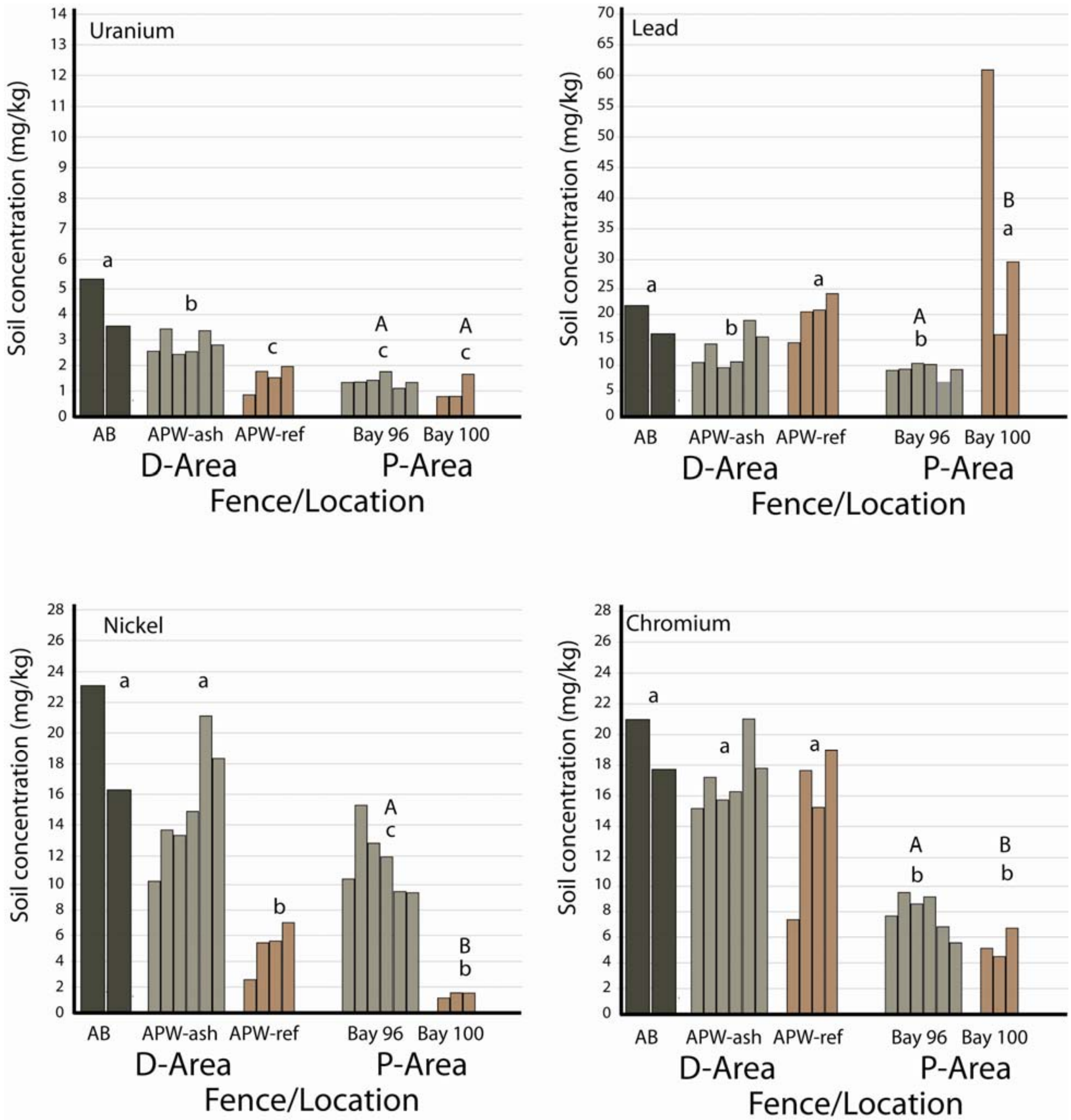

Figure 6b. Trace Element Concentrations In Surface Soil (1-15 Cm) From Each Drift Fence Location at Sample Sites In P Area And D Area (AB=Primary Ash Settling Basin, APW-Ash=Ash Plume Wetland With Ash Deposits, APW-Ref=Ash Plume Wetland With No Ash). Significant Differences Within The P-Area Sites Indicated By Upper Case Letters; Across All Sites Indicated By Lower Case

Table 7. Correlations of Surface Soil Trace Element Concentrations With Tissue Concentrations In Taxa From P Area and D Area

	Trace Element					
Biota	**V**	**Cr**	**Ni**	**Cu**	**Zn**	**As**
Amphibians	0.79[#]	0.39	-0.07	0.42	-0.06	0.77[#]
Reptiles	-0.21	-0.44	-0.36	0.13	0.57	-0.11
Small mammals	0.63[*]	-0.62[*]	-0.18	0.22	0.20	0.92[##]
Spiders	0.28	-0.08	0.31	0.23	0.16	0.85[##]
Beetles	0.36	-0.41	-0.25	-0.36	0.03	0.55[**]
Millipedes	0.34	0.44	0.63	0.38	-0.05	0.74[*]
	Se	**Sr**	**Cd**	**Hg**	**Pb**	
Amphibians	0.85[##]	0.49	--	-0.05	0.33	
Reptiles	0.35	0.30	--	--	-0.33	
Small mammals	0.67[**]	0.92[##]	--	0.19	0.22	
Spiders	0.83[##]	0.87[##]	--	-0.22	0.18	
Beetles	0.84[##]	0.97[##]	--	-0.04	0.30	
Millipedes	0.82[**]	0.64	--	--	0.14	

* *P* <0.10
** *P* <0.05
# *P* <0.01
P <0.001
-- Below method detection limits in soil or tissue

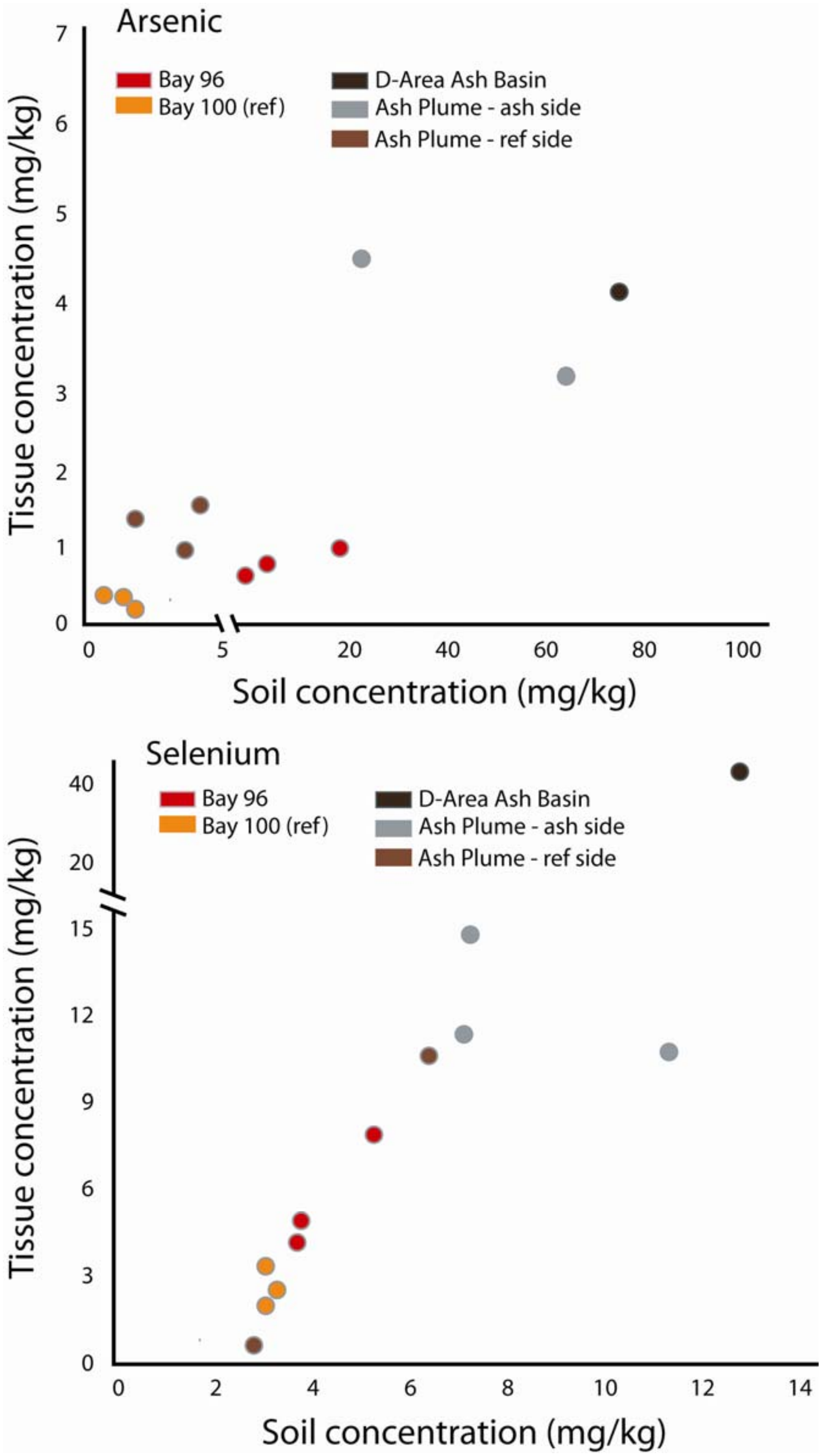

Figure 7. Relationship Between Soil Trace Element Concentration and Tissue Concentration Across The P-Area and D-Area Contamination Gradient (Top - Arsenic In Amphibians; Bottom - Selenium In Ground Beetles)

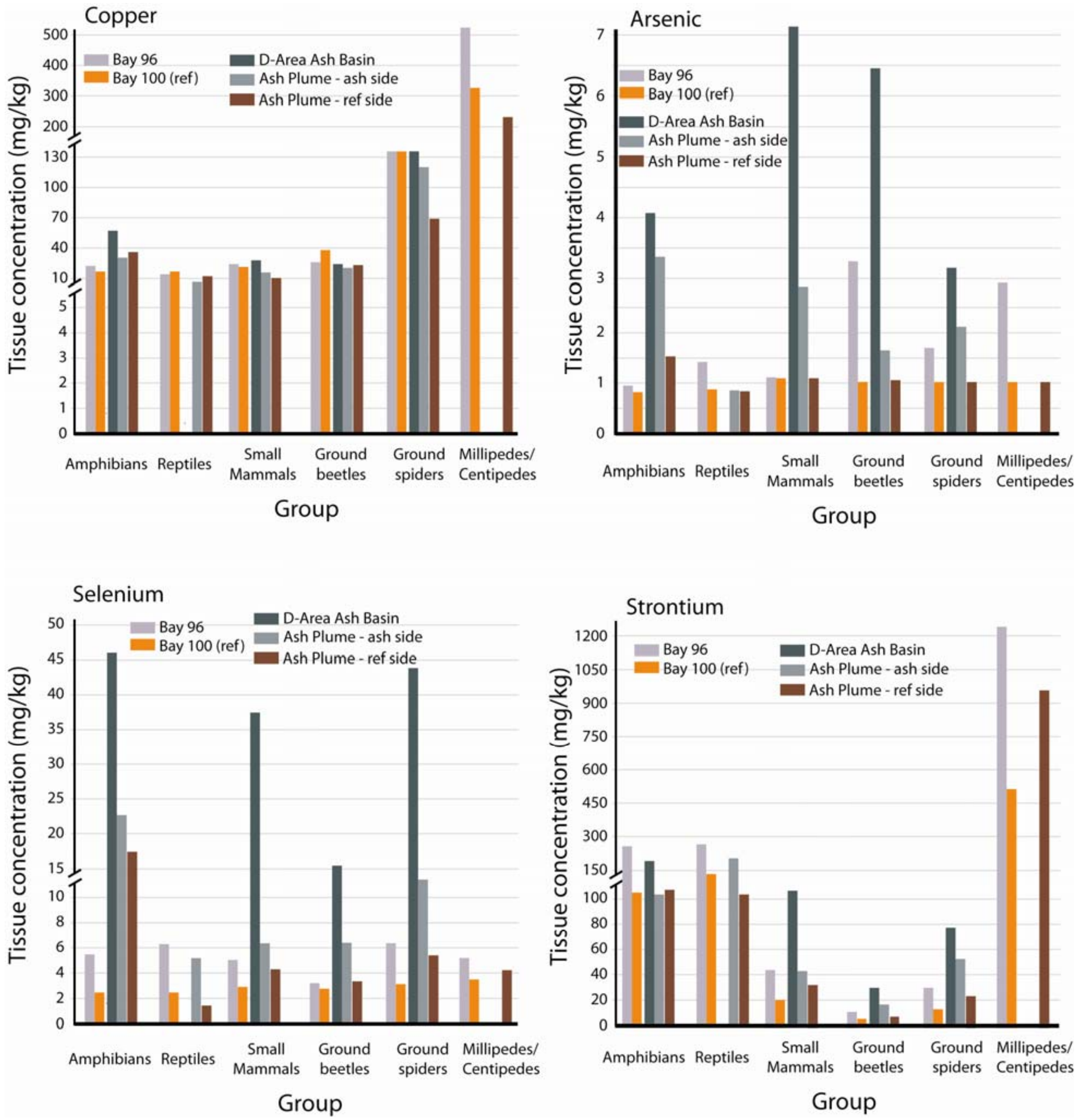

Figure 8. **Taxonomic Differences In Trace Element Concentrations For Amphibians, Reptiles, Small Mammals, Ground Beetles, Ground Spiders, And Millipedes/Centipedes Captured In Pitfall Traps At The P-Area and D-Area Drift Fence Locations**

We observed elevated levels of five trace elements (As, Sr, Fe,Co, and Tl) in the Bay 96 ash-impacted soils compared to concentrations in the two cores taken within the Bay 100 wetland. Surface soil concentrations of five additional elements (V, Cu, Ni, Zn, Cr) were elevated at the Bay 96 drift fence locations — these differences between the two sites may be related to textural differences between the wetland soils at Bay 96 fences and the bay rim/upland soils at Bay 100. Bay 100 had elevated Al and Pb levels compared to Bay 96 soils. Biota at Bay 96 had elevated tissue concentrations of As, Se, and Sr compared to biota from the reference site (Bay 100); Hg and Pb were higher in tissue at Bay 100. Elevated lead at Bay 100 may possibly be due to pre-SRS waterfowl hunting, as lead shot accumulates and settles slowly in wetland sediments (Mudge 1984). We did not observe any population-level effects related to these elevated body burdens, although chronic sub-lethal exposure studies were not conducted.

All prior SREL research on the ecological effects of CCW has been conducted within the D Area system, and conclusions may be limited to that system. Studies on amphibians exposed to CCW in the D Area receiving ponds and primary/secondary ash settling basins revealed that numerous species accumulate high concentrations of trace elements, which elicit several adverse responses (Rowe et al. 1996, 1998; Hopkins et al. 1997, 1999, 2000, 2006; Snodgrass et al. 2004). For example, southern toads inhabiting the D Area primary settling basin bioaccumulated metals (Hopkins et al. 1998), had increased stress hormones (Hopkins et al. 1997, 1999) and experienced reduced larval recruitment (Rowe et al. 2001). Narrow-mouth toads (*Gastrophryne carolinensis*) from the primary basin accumulated traced elements and transferred significant quantities of Se and Sr to their eggs, had reduced hatching success, and increased larval developmental abnormalities, abnormal swimming behavior, and overall viability (Hopkins et al. 2006). Mole salamander larvae reared in mesocosms containing ash sediments from the D Area receiving basins also accumulated trace elements and had reduced larval growth rate and survival to metamorphosis (Roe et al. 2006). These studies suggest that recently disposed CCW (i.e., in open receiving and settling basins) has sub-lethal effects on amphibians that may affect populations.

Recent D Area research (Metts et al. 2012) found that southern toads inhabiting the D-Area also maternally transferred trace elements to their eggs. In addition, these females produced smaller clutches of eggs and experienced decreased hatching success. In fact, overall reproductive success of the DAB and DAPW females was reduced 39% and 28%, respectively, compared to reference females. Furthermore, larvae from ash basin and ash plume females had a 25% decrease in survival to metamorphosis compared to reference females. Moreover, larvae reared in CCW sediments had extended larval period, were smaller at metamorphosis, and had reduced performance compared to those reared in reference sediments. These data suggest that some CCW-contaminated habitats may be an environmental “sink” to some amphibian species.

At Bay 96, tissue and sediment concentrations of COPCs were generally lower than levels in the DAPW, and much lower than the D Area settling basins (see Figs. 7, 8). For elements that showed a significant correlation between soil and tissue concentrations, Bay 96 levels were lower than DAPW and DAB levels (Fig. 7). Whether the low-level body burdens observed at Bay 96 translate to significant individual- or population-level effects is unknown.

In addition to contaminants, numerous factors influence amphibian diversity, population size, and demography. The amount of time a wetland holds water (i.e., hydroperiod) is a primary determinant of juvenile recruitment, species diversity, and species composition (Pechmann et al. 1989, Snodgrass et al. 2000). Although fewer captures of amphibians occurred at Bay 96 compared to Bay 100 for most species, the most parsimonious explanation for the reduced numbers is the hydroperiod (observed and long-term average) of the sites. During our sampling Bay 96 did not hold water; Bay 100 had pockets of water for two months, which enabled successful recruitment by mole salamanders and may have attracted breeding southern toads. The elevated tissue Hg in biota at Bay 100 also suggests a longer hydroperiod. Spadefoot toads, a short hydroperiod specialist, were more numerous at Bay 96. In addition, the drift fences at each site may have sampled different types of animals: relatively sparsely distributed residents living on the ash-impacted area at Bay 96 vs. breeding immigrants attracted to water at Bay 100.

General Habitat Observations

The ash-impacted area of Bay 96 creates a habitat unlike others we have observed on the SRS. Numerous and extensive subterranean stump and root holes, presumably a result of the original ash-flow disturbance, provide a network of refuges for ground dwelling biota.

CONCLUSION

Long-term stewardship of DOE lands and surface waters requires landscape-level management that maintains a healthy ecosystem and minimizes ecological risks from legacy contaminants such as CCW. Decisions concerning acceptable clean-up and closure of CCW sites require monitoring the diversity and success of the biota inhabiting the area, preferably by direct measurement of biological effects. In this study we documented COPC levels in soils and biota, but did not directly assess biological effects.

Past SREL research in the D-Area system has assessed the effects of CCW on vertebrates. Previous studies have documented contaminant bioaccumulation, with accompanying individual-level effects (e.g., altered behavior, increased deformities, reduced growth) and population-level effects (e.g., reduced recruitment and offspring viability) in some species, with the most deleterious effects being associated with the highest level of contaminants (i.e., in active ash settling basins). In general, biological effects in the DAPW remain elevated compared to reference sites but are below levels observed for the primary and secondary ash basins. Similarly, trace element concentrations in surface sediments in the DAPW have attenuated compared to the DAB sediments. Both the forest plant community and the amphibian community have a species composition that appears to be "normal" for the type and age of the habitat. The trace element concentrations at Bay 96 are lower than at the DAPW, and it also appears to have a typical amphibian community compared to the nearby reference site.

Site remediation decisions require an assessment of the potential ecosystem-level risk of trace element contaminants to organisms, including: 1) a species list (biological survey) for the habitat of interest for comparison to reference sites, 2) species-specific estimates of trace element concentrations (body burdens), and 3) the measurement of endpoints that reflect the individual and population-level consequences of elevated trace element body burdens (population effects). In our study, we conducted biological surveys of Bay 96, Bay 100, and select D Area sites for comparison, and determined trace element tissue concentrations in a variety of organisms. Given the time and funding constraints, we were not able to conduct extensive population demography studies or experimentally assess chronic sub-lethal effects at the observed trace metal concentrations in Bay 96. Consequently, we are relying on prior experiments at CCW levels in the D-Area system to speculate about potential CCW impacts on biota in P-Area.

In general, the biota we examined at Bay 96 had elevated As, Se, and Sr tissue concentrations compared to animals from Bay 100. Despite these differences, concentrations in Bay 96 fauna were relatively low (e.g., As, 3-6 mg/kg; Se, 0.8-3 mg/kg) compared to those captured at the D-Area Primary Ash Settling Basin (As, 3-7 mg/kg; Se, 15-46 mg/kg) and D-Area Ash Plume Wetland (As, 1.6-3.4 mg/kg; Se, 6-22 mg/kg). Tissue concentrations were highly correlated with soil concentrations for As, Se, and Sr, and soil concentrations of these COPC were elevated in the D Area system compared to P Area (Bay 96).

For amphibians, both the contaminated site (Bay 96) and the reference site (Bay 100) were similar in species richness and composition. Greater numbers of captures occurred at Bay 100, but we think this was primarily due to 1) the presence of water for portions of the sample period at Bay 100 but not at Bay 96, and 2) a difference in configuration of our sampling fences that were likely sampling animals during their breeding migration at Bay 100 but only resident animals at Bay 96. Thus, any population-level differences between the two sites were more likely due to between-site hydroperiod differences rather than any direct effects of elevated COPC at Bay 96.

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APPENDIX A

Mean (± 1 SE) tissue concentrations (mg/kg dry mass) of COPC in taxa from P-Area (Bays 96 and 100) and D-Area (AB=Primary Ash Basin, APW=Ash Plume Wetland). REF = site with no known contamination history; ASH = site with known coal combustion wastes.

Loc	Status	Species	METALS I							
			V	1 se	Cr	1 se	Ni	1 se	Cu	1 se
100	REF	*Ambystoma talpoideum*	0.158	0.01	1.301	0.79	2.855	0.54	9.556	2.54
100	REF	*A. opacum*	0.147	--	0.778	--	0.422	--	2.771	--
100	REF	*Scaphiopus holbrookii*	0.155	0.01	0.453	0.16	3.208	0	17.829	5.1
100	REF	*Bufo terrestris*	0.228	0.03	1.115	0.32	3.06	0.15	16.869	1.44
100	REF	*Gastrophryne carolinensis*	0.147	0	0.262	0	3.208	0	5.819	0.64
100	REF	*Rana clamitans*	1.613	0.56	0.735	0.16	2.515	0.35	10.525	2.5
100	REF	*Sceloperus undulatus*	0.147	--	8.125	--	4.387	--	13.716	--
100	REF	*Scincella laterale*	0.147	0	8.125	0	4.387	0	13.716	0
100	REF	*Sorex longirostris*	1.191	0.29	1.985	0.44	0.921	0.24	16.023	3.29
100	REF	*Blarina brevicaudata*	1.276	--	11.797	--	5.885	--	12.717	--
100	REF	*Peromyscus*	0.494	--	2.597	--	1.072	--	11.626	--
100	REF	Millipede	0.811	0.11	1.959	0.1	1.151	0.05	317.75	36.8
100	REF	Terrestrial spider	0.738	0.15	0.814	0.16	1.053	0.36	135.3	11.8
100	REF	Bombadier beetle	0.324	--	0.689	.	3.208	--	33.271	--
100	REF	Ground beetles	0.481	0.07	1.24	0.51	1.24	0.42	37.439	10.9
100	REF	Crickets	0.731	0.19	0.664	0.1	1.948	0.73	29.315	1.81
96	ASH	*A. opacum*	1.321	1.17	1.793	1.54	3.208	0	26.984	13.9
96	ASH	*Plethodon glutinosus*	0.344	0.14	0.904	0.64	2.574	0.63	18.215	6.27
96	ASH	*Scaphiopus holbrookii*	0.262	0.07	1.028	0.63	3.208	0	23.913	5.85
96	ASH	*Bufo terrestris*	0.303	0.11	0.796	0.21	3.047	0.15	18.068	2.08
96	ASH	*Rana clamitans*	0.494	0.17	0.529	0.13	3.208	0	10.66	1.72
96	ASH	*R. sphenocephala*	0.878	0.56	2.311	0.46	3.208	0	16.316	2.11
96	ASH	*Scincella laterale*	0.147	--	0.591	--	0.846	--	14.341	--
96	ASH	*Eumeces fasciatus*	0.147	--	0.429	--	0.455	--	16.396	--
96	ASH	*Storeria dekayi*	0.147	--	1.201	--	0.741	--	9.124	--
96	ASH	*Diadophis punctatus*	0.884	0.23	0.932	0.4	2.46	0.75	10.472	2.47
96	ASH	*Sorex longirostris*	0.449	0.03	5.273	4.54	3.15	2.44	14.876	0.47
96	ASH	*Blarina brevicaudata*	0.731	0.11	1.542	0.26	1.298	0.25	19.059	3.39
96	ASH	*Peromyscus*	0.558	0.13	3.215	1.16	2.702	0.47	26.807	5.55
96	ASH	Centipede	4.806	--	2.595	--	5.344	--	590.15	--
96	ASH	Millipede	1.357	0.53	1.814	0.64	1.992	0.52	516.47	113
96	ASH	Terrestrial spider	0.486	0.05	0.803	0.18	1.536	0.3	135.51	13.2
96	ASH	Bombadier beetle	0.415	--	0.638	--	3.208	--	29.839	--
96	ASH	Ground beetles	0.404	0.01	0.805	0.2	0.835	0.12	24.307	1.66
96	ASH	Catepillar	0.394	--	0.489	--	0.688	--	14.875	--
96	ASH	Crickets	0.372	0.04	1.061	0.67	1.368	0.37	44.143	8.15
AB	ASH	*Bufo terrestris*	0.78	0.39	0.961	0.37	1.719	0.51	11.669	4.64
AB	ASH	*Acris gryllus*	0.399	0.11	0.258	0	0.607	0.22	11.92	1.5
AB	ASH	*Gastrophryne carolinensis*	0.539	0.04	5.611	2.1	4.312	1.57	145.54	85.6
AB	ASH	*Rana catesbeiana*	5.124	0.31	1.579	0.22	1.457	0.21	48.423	7.38
AB	ASH	*R. clamitans*	4.679	0.72	1.258	0.19	2.539	0.64	68.482	21.1
AB	ASH	*R. sphenocephala*	3.192	0.29	1.764	0.2	1.818	0.23	59.347	4.83
AB	ASH	*Sorex longirostris*	2.045	--	1.341	--	0.778	--	20.542	--
AB	ASH	Terrestrial spider	0.432	0	0.484	0	0.797	0.04	135.37	12.5
AB	ASH	Bombadier beetle	0.267	--	0.341	--	1.162	--	29.65	--

Loc	Status	Species	METALS I							
			V	1 se	Cr	1 se	Ni	1 se	Cu	1 se
AB	ASH	Ground beetles	0.397	0.25	0.396	0.1	0.854	0.02	21.653	5.82
APW	ASH	*Bufo terrestris*	0.433	0.07	0.621	0.12	0.477	0.07	16.987	3.92
APW	ASH	*Gastrophryne carolinensis*	1.048	0.9	0.754	0.5	2.209	1	3.509	3.22
APW	ASH	*Rana catesbeiana*	4.615	2.49	3.589	1.62	1.808	0.69	38.497	12.1
APW	ASH	*R. clamitans*	1.86	0.73	2.887	1.06	1.859	0.81	48.756	33.1
APW	ASH	*R. sphenocephala*	2.511	0.69	1.502	0.28	1.03	0.17	16.723	8.46
APW	ASH	*Scincella laterale*	0.147	0	0.258	0	3.208	0	17.325	13.2
APW	ASH	*Eumeces fasciatus*	0.147	0	0.501	0.24	1.821	1.39	3.273	0.02
APW	ASH	*Sorex longirostris*	0.985	0.59	1.029	0.08	0.612	0.05	10.611	0.43
APW	ASH	*Blarina brevicaudata*	2.876	0.59	1.956	0.44	1.161	0.16	9.977	1.09
APW	ASH	*Peromyscus*	3.923	--	2.386	--	1.505	--	17.104	--
APW	ASH	Terrestrial spider	1.487	0.32	1.169	0.27	2.107	0.33	117.73	8.39
APW	ASH	Ground beetles	0.896	0.09	0.905	0.16	0.92	0.18	23.222	0.93
APW	ASH	Catepillar	1.178	--	0.97	--	0.657	--	12.703	--
APW	REF	*Bufo terrestris*	0.147	0	0.25	0	3.208	0	3.988	0
APW	REF	*Gastrophryne carolinensis*	0.205	0.06	0.27	0.01	0.285	0.01	4.174	0.75
APW	REF	*Rana catesbeiana*	1.821	0.77	2.063	0.65	1.777	0.46	49.086	15
APW	REF	*R. clamitans*	0.895	--	0.258	--	3.208	--	16.304	--
APW	REF	*R. sphenocephala*	1.239	--	1.095	--	0.651	--	18.077	--
APW	REF	*Eumeces fasciatus*	0.291	--	2.872	--	3.208	--	7.838	--
APW	REF	*Blarina brevicaudata*	0.692	0.19	0.872	0.22	0.616	0.03	10.244	0.62
APW	REF	Millipede	4.941	--	2.41	--	1.685	--	240	--
APW	REF	Terrestrial spider	0.432	0	0.533	0.05	0.657	0	68.885	61.8
APW	REF	Ground beetles	0.424	0.01	0.621	0.1	0.639	0.02	23.701	2.68
APW	REF	Cicada	0.69	0.17	0.619	0.16	1.477	0.87	20.205	4.69

Loc	Status	Species	METALS II							
			Zn	1 se	As	1 se	Se	1 se	Sr	1 se
100	REF	*Ambystoma talpoideum*	85.08	6.6	0.695	0	1.587	0.15	79.362	9.33
100	REF	*A. opacum*	58.32	--	0.695	--	1.83	--	44.095	--
100	REF	*Scaphiopus holbrookii*	83.83	2.53	0.695	0	2.037	0.19	187.6	13
100	REF	*Bufo terrestris*	85.88	2.17	0.695	0	2.354	0.13	113.81	5.24
100	REF	*Gastrophryne carolinensis*	155.3	13.2	0.695	0	2.402	0.3	76.99	8.54
100	REF	*Rana clamitans*	69.1	5.88	0.695	0	1.664	0.21	38.681	8.31
100	REF	*Sceloperus undulatus*	72.08	--	0.695	--	1.974	--	139.56	--
100	REF	*Scincella laterale*	72.08	0	0.695	0	1.974	0	139.56	0
100	REF	*Sorex longirostris*	81.58	4.27	1.044	0	2.842	0.42	17.492	3.26
100	REF	*Blarina brevicaudata*	95.71	--	1.047	--	2.975	--	27.331	--
100	REF	*Peromyscus*	73.29	--	1.047	--	1.495	--	15.067	--
100	REF	Millipede	274.5	7.08	1.036	0	3.375	0.45	501.22	64.1
100	REF	Terrestrial spider	345.6	26	1.028	0.07	2.727	0.2	11.522	0.99
100	REF	Bombadier beetle	74.71	--	0.695	--	4.118	--	2.707	--
100	REF	Ground beetles	91.49	5.76	1.147	0.16	2.364	0.28	3.729	0.37
100	REF	Crickets	117.8	11.6	0.866	0.1	1.84	0.37	7.765	0.7
96	ASH	*A. opacum*	113	21.9	1.815	1.12	5.468	0.99	153.83	15.9
96	ASH	*Plethodon glutinosus*	125.4	9.13	0.98	0.2	6.565	2.65	131.09	23.5
96	ASH	*Scaphiopus holbrookii*	94.32	9.21	0.695	0	5.549	0.49	606.93	93.6
96	ASH	*Bufo terrestris*	107.8	17.8	0.768	0.05	5.819	0.73	195.34	24.5
96	ASH	*Rana clamitans*	60.25	4.82	0.695	0	1.952	0.01	105.44	30.9
96	ASH	*R. sphenocephala*	87.79	20.6	1.198	0.5	3.914	1.32	78.423	21.4
96	ASH	*Scincella laterale*	151.8	--	0.695	--	1.223	--	50.691	--

Loc	Status	Species	METALS II							
			Zn	1 se	As	1 se	Se	1 se	Sr	1 se
100	REF	*Ambystoma talpoideum*	85.08	6.6	0.695	0	1.587	0.15	79.362	9.33
96	ASH	*Eumeces fasciatus*	75.61	--	0.695	--	6.326	--	184.32	--
96	ASH	*Storeria dekayi*	69.26	--	0.947	--	3.387	--	357.44	--
96	ASH	*Diadophis punctatus*	89.45	7.22	2.086	0.45	8.294	1.21	319.2	64.2
96	ASH	*Sorex longirostris*	89.79	5.94	1.045	0	4.652	1.27	18.726	2.53
96	ASH	*Blarina brevicaudata*	96.3	10.9	1.137	0.07	7.521	2.03	59.091	14
96	ASH	*Peromyscus*	104.9	17	1.047	0	2.748	0.7	67.119	18.3
96	ASH	Centipede	259.8	--	5.803	--	7.96	--	1514.5	--
96	ASH	Millipede	280.2	22	1.609	0.54	4.302	0.39	1196.9	206
96	ASH	Terrestrial spider	296.3	30.3	1.673	0.59	6.263	0.8	27.275	3.59
96	ASH	Bombadier beetle	70.39	--	0.695	--	3.93	--	8.618	--
96	ASH	Ground beetles	83.72	5.76	3.724	0.82	2.954	0.33	9.084	1.3
96	ASH	Catepillar	67.59	--	1.036	--	2.807	--	9.584	--
96	ASH	Crickets	110.3	5.41	0.91	0.06	2.663	0.34	19.21	2.5
AB	ASH	*Bufo terrestris*	60.43	18.4	1.162	0.39	7.635	3.71	205.82	120
AB	ASH	*Acris gryllus*	111.4	13	1.02	0.33	19.18	14	222.36	105
AB	ASH	*Gastrophryne carolinensis*	88.86	8.88	1.451	0.51	40.32	9.92	493.45	208
AB	ASH	*Rana catesbeiana*	66.94	6.98	4.48	0.38	47.96	1.48	97.753	10.4
AB	ASH	*R. clamitans*	63.28	6.12	3.97	0.66	58.71	3.62	168.8	46.2
AB	ASH	*R. sphenocephala*	63.97	4.68	4.853	0.53	53.73	3.03	177.26	13
AB	ASH	*Sorex longirostris*	119.8	--	7.206	--	36.97	--	109.95	--
AB	ASH	Terrestrial spider	383.8	81.6	3.239	1.12	42.64	0.54	73.724	25.2
AB	ASH	Bombadier beetle	64.97	--	2.389	--	11.79	--	15.748	--
AB	ASH	Ground beetles	149.7	79.7	8.432	7.74	16.1	6.48	31.425	10.2
APW	ASH	*Bufo terrestris*	50.25	7.25	0.695	0	9.479	4.38	150.17	10.1
APW	ASH	*Gastrophryne carolinensis*	36.87	31.2	1.609	0.91	3.498	2.28	85.031	84.8
APW	ASH	*Rana catesbeiana*	48.95	7.32	5.056	1.58	38.64	13.7	101.04	29.1
APW	ASH	*R. clamitans*	39.01	4.52	2.843	0.67	6.906	1.59	108.37	7.66
APW	ASH	*R. sphenocephala*	63.44	18	3.472	0.84	24.06	12.1	90.638	10.6
APW	ASH	*Scincella laterale*	155.7	13.8	0.695	0	7.255	1.5	193.01	101
APW	ASH	*Eumeces fasciatus*	96.2	6.5	0.695	0	3.252	0.91	165.03	53.3
APW	ASH	*Sorex longirostris*	87.73	16.8	1.319	0.28	7.825	3.6	35.767	2.64
APW	ASH	*Blarina brevicaudata*	68.47	6.39	3.309	0.56	5.482	3.27	42.947	12.7
APW	ASH	*Peromyscus*	96.54	--	4.87	--	4.432	--	59.08	--
APW	ASH	Terrestrial spider	344.8	32.2	2.105	0.4	12.11	0.77	51.062	4.2
APW	ASH	Ground beetles	90.34	8.72	1.568	0.37	5.913	0.69	14.297	1.86
APW	ASH	Catepillar	70.68	--	2.87	--	4.315	--	5.658	--
APW	REF	*Bufo terrestris*	33.16	0	0.978	0	9.326	0	89.875	0
APW	REF	*Gastrophryne carolinensis*	119.5	15.8	0.762	0.07	3.299	1.79	73.433	0.49
APW	REF	*Rana catesbeiana*	64.03	10.8	1.847	0.27	22.55	6.29	113.29	14.2
APW	REF	*R. clamitans*	46.38	--	0.695	--	11.51	--	131.68	--
APW	REF	*R. sphenocephala*	58.75	--	1.438	--	15	--	132.77	--
APW	REF	*Eumeces fasciatus*	124.3	--	0.695	--	1.223	--	106.82	--
APW	REF	*Blarina brevicaudata*	84.01	5.93	1.038	0	4.425	1.15	30.865	8.79
APW	REF	Millipede	309.6	--	1.047	--	4.013	--	953.08	--
APW	REF	Terrestrial spider	219.9	186	1.047	0	5.537	4.96	20.616	18.4
APW	REF	Ground beetles	94.49	6.9	1.045	0	3.034	0.88	3.2	0.46
APW	REF	Cicada	138.3	24.8	0.926	0.12	1.643	0.29	2.936	0.42

Loc	Status	Species	METALS III							
			Cd	1 se	Hg	1 se	Pb	1 se		

Loc	Status	Species	METALS III							
			Cd	1 se	Hg	1 se	Pb	1 se		
100	REF	*Ambystoma talpoideum*	0.262	0	1.178	0.14	1.372	0.13		
100	REF	*A. opacum*	0.262	--	1.208	--	5.518	--		
100	REF	*Scaphiopus holbrookii*	0.319	0.05	0.549	0.09	1.475	0		
100	REF	*Bufo terrestris*	0.262	0	0.66	0.04	1.635	0.14		
100	REF	*Gastrophryne carolinensis*	0.335	0.06	0.668	0.1	1.493	0.1		
100	REF	*Rana clamitans*	0.262	0	0.737	0.08	1.753	0.17		
100	REF	*Sceloperus undulatus*	0.262	--	0.696	--	0.979	--		
100	REF	*Scincella laterale*	0.262	0	0.696	0	0.979	0		
100	REF	*Sorex longirostris*	0.698	0.04	0.935	0.28	1.997	0.67		
100	REF	*Blarina brevicaudata*	0.737	--	0.581	--	2.96	--		
100	REF	*Peromyscus*	0.737	--	0.201	--	0.842	--		
100	REF	Millipede	0.636	0.05	1.697	0.18	1.377	0.13		
100	REF	Terrestrial spider	3.102	0.25	1.214	0.24	3.194	0.92		
100	REF	Bombadier beetle	0.262	--	0.569	--	1.475	--		
100	REF	Ground beetles	0.618	0.03	0.467	0.06	2.846	1.48		
100	REF	Crickets	0.422	0.09	0.261	0.03	1.5	0.19		
96	ASH	*A. opacum*	0.262	0	0.58	0.23	1.475	0		
96	ASH	*Plethodon glutinosus*	0.262	0	0.373	0.04	1.293	0.19		
96	ASH	*Scaphiopus holbrookii*	0.262	0	0.307	0	1.502	0.03		
96	ASH	*Bufo terrestris*	0.27	0.01	0.531	0.05	1.445	0.05		
96	ASH	*Rana clamitans*	0.262	0	0.781	0.06	1.475	0		
96	ASH	*R. sphenocephala*	0.262	0	0.585	0.28	1.475	0		
96	ASH	*Scincella laterale*	0.262	--	0.303	--	1.475	--		
96	ASH	*Eumeces fasciatus*	0.262	--	0.738	--	0.734	--		
96	ASH	*Storeria dekayi*	0.262	--	0.303	--	1.475	--		
96	ASH	*Diadophis punctatus*	0.766	0.23	0.663	0.1	4.088	1.6		
96	ASH	*Sorex longirostris*	0.711	0.03	0.455	0.12	0.622	0.14		
96	ASH	*Blarina brevicaudata*	0.698	0.04	0.368	0.09	0.73	0.09		
96	ASH	*Peromyscus*	0.737	0	0.201	0	0.469	0		
96	ASH	Centipede	0.582	--	0.23	--	1.826	--		
96	ASH	Millipede	0.788	0.03	0.834	0.26	0.864	0.3		
96	ASH	Terrestrial spider	2.638	0.28	0.369	0.08	1.034	0.26		
96	ASH	Bombadier beetle	0.262	--	0.303	--	1.475	--		
96	ASH	Ground beetles	0.596	0.01	0.244	0.03	0.538	0.06		
96	ASH	Catepillar	0.582	--	0.187	--	0.377	--		
96	ASH	Crickets	0.481	0.07	0.232	0.02	0.845	0.18		
AB	ASH	*Bufo terrestris*	0.262	0	0.626	0.13	1.027	0.27		
AB	ASH	*Acris gryllus*	0.262	0	0.71	0.41	1.418	0.06		
AB	ASH	*Gastrophryne carolinensis*	0.262	0	0.298	0.01	1.381	0.26		
AB	ASH	*Rana catesbeiana*	1.518	0.2	0.487	0.08	1.165	0.13		
AB	ASH	*R. clamitans*	1.787	0.07	0.679	0.19	1.475	0		
AB	ASH	*R. sphenocephala*	2.012	0.17	0.578	0.05	1.34	0.08		
AB	ASH	*Sorex longirostris*	0.737	--	0.655	--	0.595	--		
AB	ASH	Terrestrial spider	3.539	0.96	0.217	0.02	0.469	0		
AB	ASH	Bombadier beetle	0.262	--	0.303	--	1.475	--		
AB	ASH	Ground beetles	0.5	0.24	0.258	0.05	0.972	0.5		
APW	ASH	*Bufo terrestris*	0.262	0	0.423	0.07	1.475	0		
APW	ASH	*Gastrophryne carolinensis*	0.262	0	0.341	0.04	0.967	0.51		
APW	ASH	*Rana catesbeiana*	1.922	1.16	0.546	0.12	0.764	0.24		
APW	ASH	*R. clamitans*	0.262	0	0.462	0.07	0.939	0.35		
APW	ASH	*R. sphenocephala*	0.877	0.62	1.012	0.28	0.855	0.26		

Loc	**Status**	**Species**	**METALS III**							
			Cd	**1 se**	**Hg**	**1 se**	**Pb**	**1 se**		
APW	ASH	*Scincella laterale*	0.262	0	0.447	0.12	1.475	0		
APW	ASH	*Eumeces fasciatus*	0.262	0	0.303	0	1.475	0		
APW	ASH	*Sorex longirostris*	0.66	0.08	0.202	0	0.662	0.29		
APW	ASH	*Blarina brevicaudata*	0.582	0	0.193	0.01	1.278	0.22		
APW	ASH	*Peromyscus*	0.737	--	0.201	--	1.525	--		
APW	ASH	Terrestrial spider	3.777	0.19	0.429	0.09	1.003	0.23		
APW	ASH	Ground beetles	0.66	0.04	0.195	0	0.547	0.1		
APW	ASH	Catepillar	0.737	--	0.201	--	1.201	--		
APW	REF	*Bufo terrestris*	0.262	0	0.436	0	1.475	0		
APW	REF	*Gastrophryne carolinensis*	0.305	0.04	0.691	0.19	1.122	0.35		
APW	REF	*Rana catesbeiana*	0.896	0.37	0.689	0.11	1.2	0.16		
APW	REF	*R. clamitans*	0.262	--	0.455	--	1.475	--		
APW	REF	*R. sphenocephala*	0.262	--	0.416	--	0.617	--		
APW	REF	*Eumeces fasciatus*	0.262	--	0.303	--	1.475	--		
APW	REF	*Blarina brevicaudata*	0.784	0.17	0.234	0.03	0.946	0.42		
APW	REF	Millipede	2.194	--	0.681	--	2.177	--		
APW	REF	Terrestrial spider	1.907	1.77	0.197	0.17	0.566	0.1		
APW	REF	Ground beetles	0.706	0.03	0.219	0.02	0.513	0.07		
APW	REF	Cicada	1.794	0.53	0.23	0.04	1.162	0.29		

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Attachment C-3

Ecological Effects of Contaminants in the P-Area Wetlands

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Ecological Effects of Contaminants in the P-Area Wetlands

August 27, 2012

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EXECUTIVE SUMMARY

Coal combustion wastes from the P-Area ash basin have affected portions of Dunbarton Bay, a Carolina Bay wetland located near the head of the Meyers Branch valley on the Savannah River Site (SRS). Previous studies have found that levels of arsenic (As), copper (Cu), nickel (Ni), selenium (Se), and strontium (Sr) are elevated in areas impacted by ash deposition, and preliminary ecological risk assessments have identified several metals for evaluation as contaminants of potential concern. The objective of this study was to evaluate the risks posed by trace metals in coal ash to higher trophic level organisms that may feed in impacted portions of Dunbarton Bay. This was accomplished by using contaminant exposure models that assess the effects on ecological receptors of trace metals in food, water, and ingested soil. Models for the *raccoon Procyon lotor and blue heron Ardea herodias*, previously developed for use in the SRS Integrator Operable Unit (IOU) assessment program, were modified *to reflect the food sources occurring in wetlands. Input data for the models included trace metal concentrations in biota, sediment, and water collected during recent surveys of the Dunbarton Bay wetlands.*

Arsenic (As) concentrations in sediments and the tissues of potential forage organisms that may be consumed by raccoons and blue herons (i.e., amphibians, reptiles, invertebrates, and small mammals) were higher in areas affected by coal ash deposition than in uncontaminated reference areas. Other elements including selenium (Se) and strontium (Sr) were also elevated in some forage organisms collected from the areas of ash deposition. However, none of these elements were present at concentrations high enough to produce exposure doses that posed potential ecological risks to raccoons or blue herons that feed in the Dunbarton Bay wetlands. The only element that exceeded toxicity reference values was aluminum (Al), which exceeded the lowest observed adverse effect level (LOAEL) for the raccoon at both impacted and uncontaminated reference sites as a result of the incidental consumption of soil. As noted in previous reports, Al exceedances in SRS soils are common, even in reference areas, and related to naturally high Al levels in soils rather than to SRS industrial operations.

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INTRODUCTION

Coal-fired steam generation facilities produce coal combustion wastes that may contain high concentrations of As, cadmium (Cd), Se, Sr, and other trace elements. These wastes are often, discharged into open aquatic settling basins following common operational practices resulting in potential habitat use by amphibians, small mammals, and invertebrates. The accumulation of trace elements associated with these wastes may result in adverse effects on the survival, growth, and development of these organisms and could affect higher trophic level organisms through food chain transfer. The impact of coal combustion wastes, particularly on amphibians, has been the subject of considerable research on the Savannah River Site (Lance et al. 2012).

The Savannah River Site (SRS) has operated several coal plants for steam generation since the early 1950s. Coal combustion wastes from the P-Area ash basin have been released into Dunbarton Bay (DB), a Carolina Bay wetland. The ash basin releases are concentrated in a portion of Dunbarton Bay known as Bay 96 on the SRS Geographic Information System (GIS) wetlands layer. Lance et al. (2012) examined the distribution of trace elements in Bay 96. They found that levels of As, Cu, Ni, Se, and Sr at sites impacted by ash deposition were elevated when compared with sites outside the ash deposition zone. They also found that biota from Bay 96 had elevated As, Se, and Sr tissue concentrations compared with biota from Bay 100, a nearby reference area. Other findings were that biota tissue concentrations were highly correlated with soil concentrations for As, Se, and Sr, However, amphibian species richness and assemblage composition were similar between Bay 96 and Bay 100. This suggests an absence of population levels effects associated with coal ash deposition.

A human health risk assessment of the P-Area wetlands conducted by SRS Area Completion Projects (ACP) based on preliminary soil and surface water data indicated that As in soil was the primary nonradiological hazard for the industrial worker and that As and vanadium (V) exceeded surface water screening level thresholds (SRS ACP 2012). An accompanying ecological assessment indicated no constituents of potential concern (COPC) for terrestrial receptors; however, As in sediment was identified as a COPC for benthic aquatic organisms and As in water was identified as a COPC for mammalian aquatic predators. Al, barium (Ba), copper (Cu), Iron (Fe), manganese (Mn), and vanadium (V) were identified for further evaluation as COPCs for aquatic receptors based on surface water concentrations.

The objective of this study was to further evaluate the risks to ecological receptors posed by trace elements in Dunbarton Bay coal ash combustion waste depositional areas. This was accomplished by using contaminant exposure models that estimate potential contaminant doses to ecological receptors on the basis of contaminant levels in food sources, water, and ingested soil. The models were originally developed for assessing the effects of metals in the SRS Integrator Operable Units (IOUs), which correspond to the Savannah River tributaries that drain the SRS and the Savannah River (Paller et al. 2008). For this report, the models were adapted for use in the wetland ecosystems found in Dunbarton Bay.

MATERIALS AND METHODS

Study Area

The study area included Bay 96 and Bay 100, which are portions of the Dunbarton Bay wetland complex located at the head of the Meyer's Branch valley on the SRS. Coal combustion ash from the P-Area Ash Basin was deposited over much of Bay 96, which is a seasonal wetland. Bay 100 is a nearby uncontaminated reference wetland. A detailed map of the study area including the location of sample sites appears in Lance et al. (2012).

Contaminant Data

The contaminant data included in this report were from studies conducted by SRS ACP and by the Savannah River Ecology Laboratory (SREL). The SREL studies, reported in detail in Lance at al. (2012), included the collection of soil data and biota tissue data. The soil data consisted of soil core samples taken from 10 impacted sites and two control sites and replicated (n=2 or 3) surface soil samples collected from three drift fences in Bay 96 and three drift fences in Bay 100. Tissue samples were from organisms collected using the drift fences and associated pitfall traps. These organisms were grouped into three categories for this report: herptiles, invertebrates, and small mammals. Species specific information concerning the organisms included in these groups can be found in Lance et al. (2012). The SRS ACP data included 10 surface soil and two surface water samples collected from ash depositional areas in the Dunbarton Bay wetlands (SRS ACP 2012). All samples were analyzed for trace elements following procedures reported in Lance et al. (2012) or according to ACP protocols.

Contaminant Exposure Models

Contaminant exposure models were used to calculate exposure doses for metals that pose potential risks to ecological receptors through ingestion of contaminated media. These exposure doses were compared with chronic toxicity reference values (TRVs) to identify potentially hazardous constituents. Exposure point concentrations (EPCs) were calculated to represent the exposure doses for each metal in each medium. Three types of EPCs were used based on sample size and amount of data censoring. They are listed below in decreasing order of preference and frequency of usage:

1) The upper 95% confidence limit (UCL) of the mean was used as a conservative estimate of the average exposure scenario when there was sufficient uncensored data for accurate computations. UCLs were computed with ProUCL 4.0 software (Singh and Singh 2007), which identifies an appropriate UCL based on the data distribution and prevalence of censoring.
2) The maximum concentration was used when at least some data exceeded detection limits but the number of detects was insufficient (generally under five) to compute UCLs.
3) The maximum detection limit was used when all data were below the detection limit(s).

The EPCs for each medium were used in contaminant exposure models. Contaminant exposure models have been developed for the river otter *Lontra Canadensis*, belted kingfisher *Ceryle alcyon, raccoon Procyon lotor, and blue heron Ardea herodias. However, only the raccoon and blue heron models were used in this study because only these organisms are likely to feed in the habitats typical of the Dunbarton Bay wetlands.* The raccoon is omnivorous and commonly forages in wetland and floodplain habitats. The blue heron typically feeds largely on fish but is an opportunistic predator that will take amphibians, reptiles, small mammals, and invertebrates in wetlands, meadows, and other habitats. The duration of exposure for all receptors was assumed to be continuous, and the receptors were assumed to spend all of their time in the evaluation areas. These are very conservative assumptions because it is unlikely that either organism, particularly the blue heron, would obtain its entire subsistence from the habitats under study. The primary exposure pathways were assumed to be ingestion of food, surface water, and soil. Dermal and inhalation pathways were not considered because they are generally insignificant compared with ingestion pathways and insufficiently understood to properly evaluate.

For previous model applications involving SRS streams, the blue heron diet was estimated to be 95% fish, 1% crayfish, 3% amphibian, and 1% birds and mammals, and the raccoon diet was estimated to be 43% fruit, 20% grains and nuts, 18% insects, 8% crayfish, 4% herptiles, 3% rodents, 2% molluscs, 1% fish, and 1% birds. These estimates were derived from data presented in EPA (1993). However, for the Dunbarton Bay wetlands the assumed diets of the raccoon and blue heron were changed to reflect the food items present in wetland habitats (as indicated by the biota samples reported in Lance et al., 2012). The blue heron diet in the Dunbarton Bay wetlands was assumed to be 75% herptiles, 12% small mammals, 12% insects, and 1% birds. The raccoon diet in the Dunbarton Bay wetlands was assumed to be 43% fruit, 20% insects, 20% grains and nuts, 13% herptiles, 3% mammals, and 1% birds. These assumptions regarding diet are plausible because both the raccoon and blue heron are opportunistic feeders capable of making large dietary adjustments based on food availability.

Direct measurement of trace metal concentrations were available for herptiles, insects, and small mammals. Metal concentrations in fruit, and grains and nuts were computed from sediment/soil concentrations using soil-to-plant biouptake factors presented in ERD (1999a). Metal concentrations in birds were assumed to be the same as in mammals.

The contaminant exposure models followed EPA (1993), Sample et al. (1996), and ERD (1999b). Ingestion rates were based on dietary composition, gross energy content, the assimilation efficiency for each food, and the metabolic rates of the receptors. Allometric models (EPA 1993) were used to compute metabolic rates and water ingestion rates. The 9.4% soil consumption rate of the raccoon was taken from EPA (1993). The soil consumption rates of the blue heron, a species for which soil consumption data were lacking, was assumed to be 2%. Ingestion rates for all pathways were summed:

$$ED_{total} = \sum_{i=1}^{n} ED_{food\ i} + ED_{water} + ED_{soil}, \text{ where:}$$

ED_{total} = total exposure dose from all sources (mg/kg/d)

$ED_{food\ i}$ = exposure dose from ingestion of food source i

ED_{water} = exposure dose from ingestion of water

ED_{soil} = exposure dose from ingestion of soil.

The exposure dose resulting from each pathway was represented as a daily intake normalized to body weight (mg/kg/d). The raccoon and blue heron models are presented in detail in Paller et al. (2012).

Total daily exposure (ED_{total}) was compared with lowest observed adverse effect levels (LOAELs) that represented the lowest metal concentrations that cause adverse chronic effects. LOAELs were taken from ERD (1999b) and from Sample et al. (1996) LOAEL values are shown in Tables 1 and 2 and discussed more fully in Paller et al. (2008). LOAELs rather than more conservative NOAELs were used to provide a more realistic estimate of probable risks. A hazard quotient (HQ) was calculated for each metal by dividing the total exposure dose by the LOAEL.

RESULTS AND DISCUSSION

<u>Metal Concentration Data</u>

EPCs were computed for metals in soils, water, herptiles (toads, frog, salamanders, and lizards), invertebrates (primarily insects followed by spiders, and millipedes), and small mammals (shrews and mice) (Table 3). Not all metals were analyzed in all media. In Bay 96 Al, antimony (Sb), Ba, beryllium (Be), and Mn were analyzed in soils and water but not biota; and U and Sr were analyzed only in soils. In reference Bay 100 metals were not analyzed in water nor were Al, Sb, Ba, Be, and Mn analyzed in soils. To compensate for these deficiencies, data were taken from reference site SRS IOUs including Upper Three Runs-upper, Tinker Creek, Fourmile Branch-upper, Pen Branch-upper, Pen Branch-middle, and Meyers Branch. Theses IOUs are described in Paller et al. (2008). The possible effects of the preceding data gaps on the results of the exposure models will be discussed later.

A comparison of the EPCs showed that As was elevated in sediments from Bay 96 compared with the references areas (Table 3). Similarly As, Se, and Sr were elevated in biota from Bay 96. In contrast, Hg was elevated in reference site biota. These results are in agreement with findings reported in Lance et al. (2012).

Contaminant Exposure Models

The raccoon contaminant exposure model showed that Al was only the only metal in Bay 96 with an exposure dose that exceeded the LOAEL (Table 1). Aluminum also exceeded the exposure dose in the reference area (Bay 100). The large majority of the Al intake in both areas was from incidental soil consumption. Al exceedances for mammals have been observed in other SRS IOUs, including reference IOUs that are unaffected by SRS operations (Paller et al. 2008). These Al exceedances are likely related to naturally high Al levels in SRS soils. Kaolinite [$Al_2Si_2O_5(OH)_4$] is mined in the region and is a component of the SRS geological strata. Another factor to consider is the effect of Al speciation on toxicity (Klöppel et al. 1997, Gensemer 2009), which raises the possibility that total Al (the form of Al evaluated in this study) may not be appropriate to compare with the relatively low Aluminum LOAEL (19.3 mg/kg/d) recommended for use with mammals.

The blue heron model showed that the exposure doses for all metals remained below their respective LOAELs in both Bay 96 and Bay 100 (Table 2). The absence of Al exceedances in the blue heron contaminant exposure models was the result of a much higher Al LOAEL for birds than for mammals (Tables 1 and 2).

It is important to consider that data were lacking for some contaminant exposure pathways for some metals. Al, Sb, Ba, Be, and U data were lacking for the biota consumption pathway; and U and Sr data were lacking for the water consumption pathways. For Al, lack of biota data is unimportant since Al risk is largely the result of soil consumption. This may also be the case for most of the other metals given their relatively low HQs and bioaccumulation factors.

Conclusions

Arsenic was elevated in sediments and biota from Bay 96. Other metals including Se and Sr were also elevated in at least some media. However, none of these metals were present at concentrations high enough to pose potential ecological risks to raccoons or blue herons that feed in the Dunbarton Bay wetlands. The only metal that exceeded toxicity reference values was Al, which exceeded the LOAEL for the raccoon at both impacted and reference sites as a result of the incidental consumption of soil. As noted in previous reports, Al exceedances in SRS soils are common, even in reference areas, and likely related to naturally high Al levels in SRS soils rather than to SRS industrial operations.

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Table 1. Contaminant Exposure Model Results for the Raccoon. Abbreviations are as follows: LOAEL= lowest observed effect level (mg/kg/day), EXP =total exposure dose (mg/kg/day), HQ= hazard quotient (EXP/LOAEL), FRIR=fruit ingestion rate, GIR=grain ingestion rate, HIR=herptile ingestion rate, NIR=insect ingestion rate, MIR=small mammal ingestion rate, BIR=bird ingestion rate, SIR=soil ingestion rate, and WIR=water ingestion rate. Ingestion rates are expressed as a percentage of EXP.

Element	LOEL	EXP	HQ	>LOEL	FRIR	GIR	HIR	NIR	MIR	BIR	SIR	WIR
Dunbarton Bay 96												
Aluminum	19.3	22.50	1.2	Yes	0.1	0.1	0.0	0.0	0.0	0.1	99.0	0.7
Antimony	1.25	0.00	0.0		4.0	1.8	0.0	0.0	0.0	20.7	56.8	16.7
Arsenic	1.26	0.16	0.1		0.7	0.3	5.9	17.0	0.9	19.4	53.3	2.4
Barium	19.8	0.66	0.0		21.1	9.7	0.0	0.0	0.0	7.4	60.6	1.2
Beryllium	6.6	0.01	0.0		1.6	0.7	0.0	0.0	0.0	24.9	68.3	4.5
Cadmium	10	0.02	0.0		1.2	0.6	13.4	74.9	2.9	1.3	3.5	2.2
Chromium	13.4	0.11	0.0		0.5	0.2	6.8	13.8	29.1	3.1	46.0	0.6
Copper	15.4	1.92	0.1		5.0	2.3	6.7	73.2	1.1	2.9	8.7	0.0
Lead	80	0.11	0.0		1.6	0.7	7.9	7.2	0.8	6.8	74.2	0.8
Manganese	284	1.08	0.0		9.7	4.5	0.0	0.0	0.0	0.4	83.3	2.1
Mercury	0.025	0.01	0.3		1.4	0.6	43.4	42.2	8.9	0.4	2.9	0.2
Nickel	80	0.11	0.0		8.2	3.8	7.5	11.6	5.1	4.6	58.8	0.5
Selenium	0.33	0.14	0.4		1.0	0.5	30.7	36.5	5.7	6.4	17.5	1.7
Vanadium	2.1	0.16	0.1		0.5	0.2	2.1	4.0	0.6	24.4	67.0	1.3
Zinc	320	3.99	0.0		8.3	3.8	29.2	45.1	3.0	6.6	4.0	0.1
Uranium	6.13	0.24	0.0		64.7	29.7	0.0	0.0	0.0	0.0	5.6	0.0
Strontium	2630	8.27	0.0		0.7	0.3	20.9	73.8	0.7	0.0	3.5	0.0
Dunbarton Bay 100												
Aluminum	19.3	31.50	1.6	Yes	0.1	0.1	0.0	0.0	0.0	0.1	99.2	0.5
Antimony	1.25	0.01	0.0		4.6	2.1	0.0	0.0	0.0	23.8	65.3	4.3
Arsenic	1.26	0.05	0.0		0.5	0.2	13.6	37.9	1.6	11.8	32.4	2.0
Barium	19.8	0.39	0.0		21.1	9.7	0.0	0.0	0.0	7.3	60.5	1.3
Beryllium	6.6	0.00	0.0		1.7	0.8	0.0	0.0	0.0	26.1	71.5	0.0
Cadmium	10	0.02	0.0		0.9	0.4	16.5	75.9	2.2	0.9	2.5	0.7
Chromium	13.4	0.11	0.0		0.6	0.3	18.3	12.6	8.7	3.7	55.5	0.4
Copper	15.4	1.59	0.1		4.6	2.1	4.6	76.3	1.5	2.6	8.0	0.1
Lead	80	0.34	0.0		1.5	0.7	2.7	14.5	1.2	6.7	72.3	0.5
Manganese	284	0.73	0.0		9.7	4.5	0.0	0.0	0.0	0.4	83.3	2.2
Mercury	0.025	0.02	0.7		1.5	0.7	28.3	52.1	9.2	0.4	3.3	4.4
Nickel	80	0.11	0.0		6.4	2.9	27.6	8.1	5.1	3.6	45.7	0.5
Selenium	0.33	0.13	0.4		2.5	1.1	9.9	24.6	3.5	15.5	42.6	0.1
Vanadium	2.1	0.14	0.1		0.5	0.2	0.9	4.8	1.5	24.5	67.3	0.3
Zinc	320	3.30	0.0		6.0	2.7	17.5	61.2	3.7	4.7	2.9	1.3
Uranium	6.13	0.15	0.0		64.7	29.7	0.0	0.0	0.0	0.0	5.6	0.0
Strontium	2630	4.45	0.0		0.0	0.0	14.1	85.2	0.7	0.0	0.0	0.0

Table 2. Contaminant Exposure Model Results for the Blue Heron. Abbreviations are as follows: LOAEL= lowest observed effect level (mg/kg/day), EXP =total exposure dose (mg/kg/day), HQ= hazard quotient (EXP/LOAEL), IIR=insect ingestion rate, HIR=herptile ingestion rate, MIR=mammal ingestion rate, BIR=bird ingestion rate, SIR=soil ingestion rate, and WIR=water ingestion rate. Ingestion rates are expressed as a percentage of EXP.

Element	LOEL	EXP	HQ	>LOEL	IIR	HIR	MIR	BIR	SIR	WIR
Dunbarton Bay 96										
Aluminum	1100	3.84	0.0		0.0	0.0	0.0	0.2	97.5	2.3
Arsenic	12.8	0.13	0.0		15.4	51.0	6.3	14.3	11.4	1.7
Barium	41.7	0.10	0.0		0.0	0.0	0.0	28.1	67.6	4.3
Cadmium	20.0	0.03	0.0		32.5	55.9	10.0	0.4	0.4	0.7
Chromium	5.0	0.24	0.0		4.3	20.3	71.2	0.8	3.4	0.1
Copper	61.7	2.07	0.0		48.5	42.8	5.9	1.5	1.4	0.0
Lead	11.3	0.09	0.0		6.4	66.9	5.9	4.9	15.4	0.5
Manganese	9770	0.17	0.0		0.0	0.0	0.0	1.6	90.8	7.5
Mercury	0.06	0.03	0.4		8.0	78.6	13.2	0.1	0.1	0.0
Nickel	107	0.11	0.0		8.2	50.7	28.4	2.7	9.8	0.3
Selenium	1.0	0.40	0.4		9.4	76.2	11.6	1.3	1.1	0.3
Vanadium	114	0.07	0.0		6.1	30.6	6.9	30.4	24.3	1.6
Zinc	131	10.08	0.1		12.7	78.8	6.7	1.5	0.3	0.0
Uranium	160	0.00	0.0		0.0	0.0	0.0	0.0	100.0	0.0
Dunbarton Bay 100										
Aluminum	1100	5.35	0.0		0.0	0.0	0.0	0.2	98.1	1.7
Arsenic	12.8	0.07	0.0		18.9	65.4	6.3	4.8	3.8	0.8
Barium	41.7	0.06	0.0		0.0	0.0	0.0	28.0	67.3	4.7
Cadmium	20.0	0.04	0.0		29.9	62.5	6.9	0.3	0.2	0.2
Chromium	5.0	0.21	0.0		4.6	64.3	25.1	1.1	4.8	0.1
Copper	61.7	1.55	0.0		55.7	32.4	8.9	1.6	1.4	0.1
Lead	11.3	0.18	0.0		20.0	35.4	13.0	7.5	23.6	0.5
Manganese	9770	0.11	0.0		0.0	0.0	0.0	1.6	90.8	7.6
Mercury	0.06	0.05	0.8		13.0	67.7	18.2	0.1	0.2	0.8
Nickel	107	0.27	0.0		2.5	81.0	12.2	0.9	3.3	0.1
Selenium	1.0	0.16	0.2		14.4	55.8	16.4	7.4	5.9	0.1
Vanadium	114	0.06	0.0		7.7	14.5	19.5	32.2	25.8	0.4
Zinc	131	6.21	0.0		23.1	63.8	11.0	1.5	0.3	0.4
Uranium	160	0.00	0.0		0.0	0.0	0.0	0.0	100.0	0.0

Table 3. Exposure Point Concentrations (EPCs, mg/kg or mg/l [water]) and number of measurements (N including non-detects [NDs]) for elements in sediment, water, herptiles, invertebrates, and small mammals collected from ash plume wetlands (Bay 96) and reference wetlands (Bay 100) in the Dunbarton Bay wetland system. Other reference data are also included as noted.

	Soil			Water			Herps			Inverts			Mamm		
	N	NDs	EPC	N	NDs	EPC	N	NDs	EPC	N	NDs	EPC	N	NDs	EPC
Bay 96															
Al	10	0	5214.0	2	0	1.930	0			0			0		
Sb	10	10	0.33	2	1	0.005	0			0			0		
As	28	3	20.06	2	1	0.047	42	32	0.618	36	21	1.172	14	12	0.455
Ba	10	0	93.39	2	0	0.094	0			0			0		
Be	10	0	1.46	2	2	0.005	0			0			0		
Cd	28	26	0.15	2	2	0.005	42	38	0.165	36	23	0.602	14	14	0.175
Cr	28	0	11.37	2	0	0.008	42	12	0.473	36	1	0.624	14	0	9.865
Cu	28	0	39.11	2	1	0.005	42	0	8.483	36	0	60.30	14	0	6.935
Pb	28	1	18.75	2	2	0.010	42	31	0.560	36	21	0.334	14	7	0.292
Mn	10	0	211.00	2	0	0.277	0			0			0		
Hg	28	18	0.05	2	2	0.002	42	14	0.216	36	18	0.137	14	7	0.216
Ni	28	1	15.47	2	1	0.007	42	37	0.551	36	10	0.557	14	4	1.835
Se	28	9	5.90	2	2	0.030	42	1	2.897	36	2	2.245	14	0	2.630
V	28	0	24.32	2	0	0.025	42	22	0.211	36	23	0.265	14	9	0.282
Zn	28	1	36.98	2	0	0.033	42	0	76.38	36	0	77.02	14	0	38.57
U	18	2	3.09	0			0			0			0		
Sr	18	1	68.25	0			42	0	113.8	36	0	261.7	14	0	18.10
Bay 100															
Al	**268***	**1**	**7314.0**	**232**	**52**	**2.003**	0			0			0		
Sb	**246**	**208**	**2.09**	**53**	**51**	**0.007**	0			0			0		
As	5	0	3.69	**66**	**61**	**0.012**	46	46	0.436	22	18	0.790	6	6	0.251
Ba	**271**	**12**	**55.20**	**76**	**10**	**0.061**	0			0			0		
Be	**231**	**112**	**0.33**	**94**	**71**	**<0.001**	0			0			0		
Cd	5	5	0.15	**233**	**216**	**0.002**	46	42	0.270	22	13	0.809	6	6	0.177
Cr	5	0	13.87	**265**	**240**	**0.005**	46	19	1.282	22	0	0.577	6	0	2.983
Cu	5	0	29.82	**281**	**198**	**0.023**	46	0	4.843	22	0	52.12	6	0	7.906
Pb	5	0	58.22	**253**	**213**	**0.019**	46	31	0.602	22	3	2.128	6	0	1.315
Mn	**249**	**2**	**142.90**	**219**	**26**	**0.190**	0			0			0		
Hg	5	5	0.13	**301**	**224**	**0.009**	46	3	0.313	22	3	0.376	6	1	0.499
Ni	5	1	12.30	**255**	**208**	**0.007**	46	41	2.085	22	12	0.401	6	1	1.874
Se	5	0	12.90	**74**	**71**	**0.002**	46	6	0.841	22	2	1.362	6	0	1.473
V	5	0	22.45	**36**	**27**	**0.005**	46	29	0.087	22	4	0.29	6	0	0.696
Zn	5	0	22.02	**274**	**133**	**0.505**	46	0	38.04	22	0	86.49	6	0	39.01
U	5	0	1.92	**0**			0			0			0		
Sr	0			**0**			46	0	41.2	22	0	162.4	6	0	9.841

* Numbers in bold represent data from reference SRS IOUs including Upper Three Runs-upper, Tinker Creek, Fourmile Branch-upper, Pen Branch-upper, Pen Branch-middle,and Meyers Branch (Paller et al. 2008).

Attachment C-4

**Earthworm *(Eisenia foetida)* Toxicity and Bioaccumulation Studies
Conducted on Soils Collected from the D-Area Wetland,
July - August 2003**

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EARTHWORM *(Eisenia foetida)* TOXICITY AND BIOACCUMULATION STUDIES CONDUCTED ON SOILS COLLECTED FROM THE D-AREA WETLAND, JULY - AUGUST 2003

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Executive Summary

Earthworm toxicity tests were conducted on soils collected from six locations at the D-Area Wetland, including two reference locations and four locations that contained coal ash. Contaminant body burdens were measured in the earthworms at the end of the toxicity tests. Arsenic was the contaminant of greatest interest because arsenic concentrations in the soils that contain coal ash were close to the ORNL Invertebrates Soil Screening Benchmark value of 60 mg/kg and exceeded the EPA Region 4 Soil Screening Benchmark of 10 mg/kg.

The results of the toxicity tests conducted on earthworms exposed to soils collected from six locations in the D-Area Wetland indicate that exposure to the soils did not cause significant mortality to the earthworms. All of the earthworm treatments, including those exposed to uncontaminated soils, experienced significant weight loss, which suggests that the soils did not contain sufficient digestible organic matter to provide adequate nourishment.

The results of the body burden analyses for arsenic indicate that all of the worms, including those exposed only to the worm bedding in which the worms were reared, had elevated body burdens of arsenic. These results suggest prior exposure to arsenic. However, arsenic concentrations were not elevated in the worm bedding, so the source of the contamination is unknown. Arsenic body burdens were similar in worms exposed to reference soils and soils from the D-Area wetland that contained coal ash, which indicates little if any uptake of arsenic from the contaminated soils.

Earthworms exposed to some of the soils that contained coal ash had significantly higher body burdens of several metals, including molybdenum, selenium, antimony, and strontium. It is doubtful, however, that most of the differences are great enough to be biologically significant.

Soil from the D-Area Wetland that contained coal ash had higher concentrations of arsenic, selenium, molybdenum, antimony and strontium than did soils collected from the reference locations. The reference soils had higher concentrations of cadmium, manganese, lead , and zinc than the soils that contained coal ash. When compared to ORNL and EPA Region 4 soil screening benchmarks, the only constituent that exceeded the ORNL benchmark was mercury, which was found at concentrations of 0.08 to 0.12 mg/kg in the reference soils and 0 12 to 0.25 mg/kg in the soils that contained coal ash. Reference soils had concentrations of manganese, mercury, selenium, vanadium, and zinc that were higher than the EPA Region 4 values. These data suggest that the EPA Region 4 benchmarks are probably overprotective. For soils that contained coal ash, there were seven EPA Region 4 benchmark values that were exceeded (arsenic , copper, mercury, manganese, molybdenum, selenium, and vanadium).

1.0 Introduction

The D-Area Wetland is located to the west of the D-Area ash basins and consists of 35.8 hectares (88 .5 acres) of wetland that received inputs of coal ash in the 1960's. Some portions of the wetland contain deposits of coal ash up to 2 meters in depth. Contaminants of concern (COCs) include arsenic and selenium associated with the coal ash. In order to evaluate bioavailability of the COCs, earthworm toxicity tests and bioaccumulation studies were performed on samples of soil collected from the wetland. Arsenic was the contaminant of greatest interest because arsenic concentrations in the soils that contain coal ash were close to the ORNL Invertebrates Soil Screening Benchmark value of 60 mg/kg (Efroymson et aI., 1997) and exceeded the EPA Region 4 Soil Screening Benchmark of 10 mg/kg (EPA, 2001).

Earthworms play a major role in the development and maintenance of soil structure, in the breakdown of organic matter in the soil, and as a source of food for terrestrial organisms (Edwards and Bohlen, 1996). Their close contact with the soil and ingestion of soil as a food source provide multiple routes of exposure and uptake of soil contaminants. Earthworms are a food source of many predators, including birds, small mammals and reptiles. Ingestion and assimilation of contaminated earthworms by these species may lead to transfer of contaminants throughout the foodchain. Therefore, earthworm toxicity tests and body burden analyses can be very useful tools in assessing ecological risks associated with contaminated soils.

2.0 Methods

2.1 Soils

Soils were collected from 6 locations at the D-Area Wetland (D2, D4, G10, H5, J6, and K4). D2 and D4 were reference locations that contained no coal ash. The remaining four locations were all collected from the area of coal deposition and were selected to have intermediate or high concentrations of arsenic and selenium.

Approximately 1 kg of soil was collected at each location. The samples were placed in plastic bags and returned to the laboratory for processing and analyses. In the laboratory, a sample of each soil was dried at 105 ºC for at least 24 hours. Percent organic content was determined by weighing approximately 10 g of the dried soil to the nearest 0.0001 g, ashing the sample in a crucible at a temperature of 550 ºC for three hours, cooling the sample in a dessicator and reweighing. Organic matter was reported as the difference between dry and ashed weight. Soil pH was measured by placing 5 g of soil in a beaker and adding ~15 ml of deionized water to the beaker. The beaker was then placed on a magnetic stirring plate and stirred for at least 10 minutes. pH was then measured using a Hach I Model 43800 pH meter that had been calibrated with pH 4 and 7 buffers.

2.2 Earthworm Culture Methods

The *Eisenia foetida* earthworms used in these experiments were obtained from the Topline Wholesale Distributing Company, Rio Rancho, New Mexico in April 2003. Upon receipt, the worms were cultured in composted horse manure amended with crushed egg shells to supply nutritional calcium. Additional composted manure was added to the surface of the cultures weekly to provide additional food. All worms used in the toxicity tests were clitellid adults, with an average weight of greater than 300 mg.

2.3 Earthworm Toxicity Tests

Toxicity tests were conducted using the methods described by EPA (1996) and summarized as follows. Approximately 200 g of soil was wetted sufficiently to attain ~75 % water holding capacity. The soil was divided into three equal quantities and each aliquot was placed in a glass pint canning jar. Ten adult clitellid earthworms, with average weights of at least 300 mg, were placed on the surface of the soil in each sample jar and the lids were loosely screwed onto the jar. The jars were placed in an incubator at 22°C ± 2 °C. At the end of 7, 14, 21, and 28 days, survival rates were determined by gently emptying the soil from the jars onto a tray and counting the number of worms in the soil. After the 7, 14, and 21-day observations, the soil was returned to the jars and the worms were placed back on the surface of the soil. At the end of the 28 day tests, the worms from each jar were counted, rinsed with deionized water, and weighed. The worms were then placed in moist filter paper in a petri dish. The petri dishes were placed in a darkened container and returned to the incubator for 24 hours in order to clear the gut contents of the worms. The worms from each replicate were then transferred to a clean vial and frozen for contaminant analyses. Endpoints of the toxicity tests were mortality and percent weight loss (as compared to the reference soil).

2-Chloracetamide was used as a reference toxicant in the toxicity tests (La Tier and Landis, 1993). Three concentrations of 2-chloracetamide were added to a synthetic reference soil that consisted of 70% fine silica sand (70 mesh), 20% kaolin clay, and 10% peat moss. The synthetic soil was then hydrated to 75% moisture content. The 7-day and 14-day LC_{50} values of the reference toxicant were determined. A negative control was also established using the synthetic soil without 2-chloracetamide, in order to determine survival rates in the absence of the toxicant. The reference toxicant data were analyzed statistically using the Moving Average Method (EPA, 1996). Statistical analysis was conducted using the CT-Tox Multimethod Computer Program (CTDEP, 1989).

3.0 Results

3.1 Reference Toxicant Test

A reference toxicity test was conducted using laboratory cultured earthworms, *Eisenia foetida*, in a mixture of artificial soil spiked with the toxicant, 2-chloroacetemide. This was a 14-day test, which followed procedures outlined in the departmental methods for toxicity testing with *Eisenia foetida.* The test was initiated July 21 and ended August 4, 2003. The following table summarizes test results.

Table 1. Results of Reference Toxicant Test with 2-Chloracetamide

Toxicant Concentration *(mg/kg)*	**7-day Survival**			
	Replicate 1	**Replicate 2**	**Replicate 3**	**Overall**
Control	100 %	100 %	100 %	100 %
19.25	80%	100 %	100 %	93 .3%
28.5	100 %		100 %	96.7%
38.5	30%	30%	10 %	23.3%
Toxicant Concentration *(mg/kg)*	**14-day Survival**			
	Replicate 1	**Replicate 2**	**Replicate 3**	**Overall**
Control	100 %	100 %	100 %	100 %
19.25	80%	100 %	100 %	93 .3%
28.5	100 %		100 %	96.7%
38.5	30%	30%	10 %	23.3%

Based on these data, 7-day and 14-day LC_{50s} of 35.1 mg/kg were calculated using the probit method (EPA, 1996). This method of LC_{50} calculation gave the most reliable upper and lower 95% confidence limits (35.115 and 35.099, respectively) when compared to the trimmed Spearman-Karber, moving-average angle, or binomial methods. Statistical analysis was conducted using the CT-Tox Multimethod Computer Program (CTDEP, 1989). The LC_{50} of 35.1 mg/kg is very close to the reported value of 38.5 mg/kg (Edwards, 1984), which suggests that earthworms from this culture are appropriately sensitive to toxicants.

3.2 Soil Parameters

The pH and organic content of each soil sample was measured as described in the Methods section.

The pH of the D-Area Wetland soil locations that were tested ranged from 4.79 to 6.31 (Table 2). The pHs of the two uncontaminated reference locations were almost identical (5.57 and 5.58). The artificial reference soil had a pH of 5.53. All of the soils are within the range of acceptable soil pH's for earthworm toxicity testing.

The percent organic content of the D-Area Wetland soils ranged from 18.8% to 22.6%. These percentages were considerably higher than those of the two reference locations, which contained 7.6% (02) and 10.5% (04) organic matter. Soils at the reference locations consisted of a silty clay, with a thin layer of organic detritus at the surface. In contrast, the soils from the D-Area Wetland consisted primarily of coal ash, but also contained a relatively thick layer of organic detritus at the surface. The percent organic content of the artificial reference soil was 11 .8%. All of the organic material in this soil was peat moss, which is a poor source of nutrition for earthworms.

The percent moisture of the two reference locations was 28.2% at D2 and 35.3% at D4. All of the locations that contained ash had higher percent moisture, ranging from 46% (J6) to 55.9% (H5). Due to a very wet spring and summer, much of the D-Area wetland contained standing water until just a few days before sampling, which accounts for the exceptionally high moisture content of these soils.

Table 2. pH, % Organic Matter and % Moisture of Soils Used for Toxicity Testing

Location	pH	% Organic Matter	% Moisture
Artificial reference soil	5.53	11 .8	52.4
D2 (dry reference soil)	5.58	7.6	28.2
D4 (wet reference soil)	5.57	10.5	35.3
G10	5.84	21.2	51.2
H5	6.31	22.6	55 .9
J6	5.67	19.2	46.0
K4	4.79	18.8	48.1

3.3 Toxicity Tests on O-Area Wetland Soils

Toxicity tests were performed on soils collected from four locations within the area of coal ash at the D-Area Wetland, and two uncontaminated reference locations and a synthetic reference soil comprised of fine sand, kaolin clay, and peat moss. The results of the toxicity tests from both the D-Area Wetland and the SRS background soil were statistically compared to the results from the synthetic reference soil. A mortality rate of ≤20% is required for the synthetic reference soil for the test result to be acceptable.

Mortality

The mortality rate in the synthetic reference soil averaged 3.3% (Table 3). Mortality rates in the two reference soils collected in the D-Area wetland also averaged 3.3%, while mortality rates in the waste site soils ranged from 0 to 3.3%. The data were not analyzed statistically because none of the toxicity tests conducted on SRS soils had mortality rates that exceeded those of the synthetic reference soil. Some low level of mortality is to be expected in the tests, since there is very little organic matter present in the synthetic reference soil or in the waste site soils to nourish the worms during the 28 day test. These results indicate that none of the soils that were tested resulted in a significant level of mortality during the 28-day exposure period.

Toxicity data from the literature suggest that arsenic results in acute toxicity when present in soil at concentrations of around 400 to 500 ppm (Vaughan and Greenslade, 1998) and chronic toxicity at concentrations of about 70 to 120 ppm (Vaughan and Greenslade, 1998; Fisher and Koszorus, 1992). However, soil chemistry can greatly affect the bioavailability and toxicity of arsenic and other metals (Lock and Janssen, 2001).

Table 3. Mortality Rates of O-Area Wetland Soils, Background Soil, and Synthetic' Reference Soil

Sample ID	# Dead*	% Mortality	Significant
Artificial reference soil	1	3.3	
D2 (dry reference soil)	1	3.3	No
D4 (wet reference soil)	1	3.3	No
G10	1	3.3	No
H5	0	0.0	No
J6	1	3.3	No
K4	0	0.0	No

Weight Loss

The earthworms were weighed at the beginning of the toxicity tests and again at the end of the tests, prior to gut clearing. The mean percent weight loss of the earthworms in each treatment is presented in Table 4. All of the earthworms, including those from the two reference locations experienced a substantial decline in weight. Overall percent weight losses ranged from 39.2% in soil from location J6 to 48.5% in soil from location G10. Percent weight loss at the two reference location ranged from 40.6 to 41.9%.

Table 4. Mean Percent Weight Loss per Individual

Sample ID	Mean % Wt Loss	Significant
D2 (dry reference soil)	41.9	
D4 (wet reference soil)	40.6	
G10	48.5	No
H5	44.6	Yes
J6	39.2	No
K4	42.3	No

The data for the two reference locations were pooled to serve as a single set of reference data. Data from the four locations that contained coal ash were then statistically compared to the pooled reference data. The data were analyzed statistically using an F-test to determine whether variances were equal or unequal, followed by a T-test for equal or unequal variances. For three of the soils (H5, J6, and K4), the variances for percent weight loss were quite high (percent weight loss varied considerably among replicates), while variances for the D2, D4, and H5 data sets were low. There is no obvious explanation for the variation in weight loss. The results showed a significant weight loss only at Location H5. The result was significantly different for this location and not G10 (which had the greatest percent weight loss) because of a higher variance for the G10 data. The data indicate that there was a substantial weight loss in the earthworms exposed to all of the locations (including the reference locations). Although weight loss can result from physiological stress associated with contaminants, such as metals, it can also result from insufficient organic matter or poor quality organic matter (high carbon; low nitrogen) in the soil that is being tested. Because all of the treatments, including the reference soils, resulted in similar weight losses, the weight loss is probably related to poor nutrition, rather than metal exposure.

Body Burden Analyses

Subsequent to the completion of the toxicity tests, the earthworms were analyzed for 12 elements (Table 5). Many of the elemental analytes are common soil constituents and/or are normally present in biota and do not cause toxicity unless present at extremely high levels. All of the elemental analytes are present in uncontaminated soils in trace amounts or higher. The analyte of most interest at the D-Area Wetland is arsenic. Arsenic was higher than expected in all of the earthworms, including those from the worm bedding that were not exposed to any of the D-Area soils. Typical arsenic concentrations in earthworms that have been raised in uncontaminated soils are generally less than 2 mg/kg (Beyer and Cromartie, 1987). Worms not exposed to any soils from the D-Area wetland, but taken directly from the composted manure (worm bedding) had an arsenic body burden of 107 mg/kg, which strongly suggests that the bedding was contaminated. However, an analysis of the worm bedding (see Table 7) indicates that the bedding did not contain elevated arsenic. Subsequently, analyses for arsenic were performed on batches of spent worm bedding from April, June and August, and none showed elevated arsenic (range of 3.8 to 5.7 mg/kg). Therefore, the source of the arsenic in worms exposed only to the worm bedding is unknown. It is possible that the worms were contaminated prior to receipt. However, this is unlikely, because they were received in April and maintained in composted horse manure for 4 months prior to initiation of the D-Area wetland tests. The elevated concentrations of arsenic in the unexposed worms make it exceedingly difficult to draw any meaningful conclusions regarding arsenic bioaccumuiation and toxicity. However, the data indicate that the arsenic body burdens of earthworms exposed to contaminated soils (98.86 to 199.49 mg/kg) were no higher than those exposed to the D-Area reference soils (D2 and D4), where body burdens ranged from 150 to 213 mg/kg, which suggests that the worms did not accumulate significant amounts of arsenic from the contaminated soils.

Worms exposed only to the worm bedding also had elevated concentrations of mercury (9.68 mg/kg), as compared to <1 mg/kg in all of the other soils. Mercury was higher in the worm bedding (Table 7) than in the other soils, which suggests that the composted manure that was used as worm bedding was the source of the mercury.

Table 5. Elemental Body Burdens (mg/kg dry weight) of Earthworms Exposed to Soils from the D-Area Wetland

Element	Worm Bedding	D2	D4	G10	H5	J6	K4
As	107.42	150.46	212.81	199.49	117.33	194.91	98.86
Cd	3.48	4.01	4.39	3.93	1.81	4.07	1.35
Cu	26.32	33.41	33.36	29.49	37.41	29.06	39 .62
Hg	9.68	0.24	0.29	0.26	0.13	0.16	0.07
Mn	32.01	51.44	44.57	11 .70	11 .99	10.71	8.27
Mo	0.61	0.41	0.44	1.12	0.78	0.65	0.37
Pb	4.06	2.86	2.56	2,56	2.90	2.58	3.57
Sb	0.04	0.04	0.06	0.13	0.06	0.09	0,07
Se	2,32	3.97	4.47	17.85	9.32	12.04	4.27
Sr	34.92	137.50	129.93 ·	210.94	242.81	162.74	214,66
V	0.37	2.10	1.38	1.57	1.52	1.14	1.23
Zn	140.56	121 .72	126,21	129.57	123.67	126.21	118.70

The body burdens of analytes from earthworms exposed to two uncontaminated reference soils (D2 and D4) were compared statistically to the body burdens of earthworms exposed to the four O-Area Wetland soils (Table 6). The results indicate that several of the analytes, including Mo, Se, Sb, and Sr were found at statistically significant higher concentrations some of the waste site soils. It is doubtful, however, that some of the differences are great enough to be biologically significant.

Table 6. Locations Where Earthworm Body Burdens were Significantly Higher ($p \leq 0.05$) than Body Burdens in Earthworms Exposed to the Uncontaminated Background Soil (D2 and D5)

Analyte	G10	H5	J6	K4
As				
Cd				
Cu				
Hg				
Mn				
Mo	*	*		
Pb				
Sb	*			
Se	*	*	*	
Sr	*	*		*
V				
Zn				

Table 7 compares soil and earthworm body burdens and bioaccumulation factors (BAF) for 10 analytes. Soil from the D-Area Wetland that contained coal ash had higher concentrations of arsenic, selenium, molybdenum, antimony and strontium than did soils collected from the reference locations. The reference soils had higher concentrations of cadmium, manganese, lead, and zinc than the soils that contained coal ash. The higher concentrations of these metals in the reference soils are probably related to the higher clay content of the reference soils.

In order to determine which metals were bioaccumulating, bioaccumulation factors (BAF) were calculated by dividing the concentration of a metal in the earthworms by the concentration in the soil. BAFs >1 indicate some degree of bioaccumulation. The data indicate that earthworms exposed to all of the soils had much higher concentrations of arsenic than the soils to which they were exposed. However, due to the very high body burdens in worms not exposed to any known source of arsenic, the only conclusion that can be drawn from these data is that arsenic will bioaccumulate in *Eisenia foetida.* Beyer and Cromartie (1987) measured arsenic concentrations in various species of earthworms collected from 20 different contaminated and uncontaminated sites and reported that arsenic does not bioaccumulate to any appreciable degree. Sample et al. (1998, 1999) developed bioaccumulation models for a number of contaminants in earthworms and reported a calculated a mean uptake factor of 0.258 for arsenic in earthworms, which indicates that arsenic is not bioaccumulated. However, other researchers have reported that arsenic does bioaccumulate in earthworms. Lock and Janssen (2001) suggest that soil characteristics, especially cation exchange capacity and pH can greatly affect metal bioavailability and toxicity. It is likely that the conflicting opinions regarding the bioavailability of arsenic is related to differing soil chemistries among the studies.

Table 7. Comparison of Soil and Earthworm Body Burdens and Bioaccumulation Factors (BAF) For 10 Analytes

Element	Media	Worm Bedding	02	04	G10	H5	J6	K4
As	Worm	107.42	150.46	21,281	199.49	11,733	194.91	98.86
As	Soil	2.84	3.26	4.84	36.25	55.08	41.22	50.76
	BAF	37.8	46.2	44.0	5.5	2.1	4.7	1.9
Se	Worm	2.32	3.97	4.47	17.85	9.32	1,204	4.27
Se	Soil	0.54	1.87	3.21	10.25	7.93	6.51	4.78
	BAF	4.3	2.1	1.4	1.7	1.2	1.8	0.9
Cd	Worm	3.48	4.01	4.39	3.93	1.81	4.07	135
Cd	Soil	0.26	0.14	0.2	0.26	0.39	0.35	0.14
	BAF	13.4	28.7	21.9	15.1	4.6	11.6	9.6
Cu	Worm	26.32	33.41	33.36	29.49	37.41	29.06	39.62
Cu	Soil	40.97	22.57	37.48	42.32	31.1	30.3	30.93
	BAF	0.6	1.5	0.9	0.7	1.2	1.0	1.3
Hg	Worm	9.68	0.24	0.29	0.26	0.13	0.16	0.07
Hg	Soil	2.77	0.08	0.12	0.25	0.14	0.12	0.12
	BAF	3.5	3.0	2.4	1.0	0.9	1.3	0.6
Mn	Worm	32.01	51.44	44.57	11.70	11.99	10.71	8.27
Mn	Soil	239.97	1,087.01	1,540.75	174.02	305.51	98.94	28.38
	BAF	0.1	0.0	0.0	0.1	0.0	0.1	0.3
Mo	Worm	0.61	0.41	0.44	1.12	0.78	0.65	0.37
Mo	Soil	2.15	0.25	0.31	7.23	8.77	6.38	4.34
	BAF	0.3	1.6	1.4	0.2	0.1	0.1	0.1
Pb	Worm	4.06	2.86	2.56	2.56	2.90	2.58	3.57
Pb	Soil	36.4	20.28	32.59	17.97	1,039	9.07	9.17
	BAF	0.1	0.1	0.1	0.1	0.3	0.3	0.4
Sb	Worm	0.04	0.04	0.06	0.13	0.06	0.09	0.07
Sb	Soil	0.01	<0.01	<0.01	0.25	0.2	0.23	0.12
	BAF	4.1			0.5	0.3	0.4	0.6
Sr	Worm	34.92	137.50	129.93	210.94	242.81	162.74	214.66
Sr	Soil	115.18	22.72	38.85	235.72	207.97	160.57	95.75
	BAF	0.3	6.1	3.3	0.9	1.2	1.0	2.2
V	Worm	0.37	2.10	1.38	1.57	1.52	1.14	1.23
V	Soil	4.65	46.67	59.83	55.03	41.25	35.42	35
	BAF	0.08	0.05	0.02	0.03	0.04	0.03	0.04
Zn	Worm	140.56	121.72	126.21	129.57	123.67	126.21	118.70
Zn	Soil	232.44	68.44	104.15	45.86	37.55	26.88	18.43
	BAF	0.6	1.8	1.2	2.8	3.3	4.7	6.4

Other metals with BAFs greater than 1 in earthworms exposed to soils from the D-Area wetlands included selenium (0.9 to 1.8), cadmium (4.6 to 15.1), copper (0.7 to 1.3), strontium (0.9 to 2.2), and zinc (2.8 to 6.4). Sample et al. (1999) report uptake factors of 1.80 for Se, 17.10 for Cd, 0.75 for Cu, and 5.77 for Zn, which generally agree with the BAFs calculated for earthworms exposed to soils from the D-Area wetland.

3.4 Comparison of Soil Concentrations to Soil Benchmark Values

Numerous soil screening benchmark data sets developed by various scientific and regulatory groups. Probably the most relevant values for the D Area wetland are those developed by Oakridge National Laboratory (Efroymson et al. [1997]) and U.S. EPA Region 4 (EPA 2001). Table 8 lists the screening benchmark values and also the range of concentrations found in soils from the D Area wetland reference soils and soils collected from sites that contained coal ash. In most instances, the EPA Region 4 screening values are much lower than the ORNL values.

Table 8. Soil Screening Benchmark Concentrations and D-Area Wetland Concentrations (All Concentrations in mg/kg)

Analyte	ORNL	EPA Region 4	D-Reference	D-Coal Ash
As	60	10	3 - 5	41 - 55[b]
Cd	20	1.6	<1	<1
Cu	50	40	23 - 37	30 - 42[b]
Hg	0.1	0.1	0.08 - 0.12	0.12 - 0.25[a,b]
Mn	-	100	1,088 – 1,541[b]	28 - 306[b]
Mo	-	2	<1	4 - 9[b]
Pb	500	50	20 - 33	9 - 18
Sb	-	3.5 0.	<1	<1
Se	70	0.81	2 -3[b]	5 - 10[b]
V	-	2	47 - 60[b]	35 - 55[b]
Zn	100	50	68 - 104[b]	18 - 46

[a] soil concentration exceeds ORNL benchmark
[b] soil concentration exceeds EPA Region 4 benchmark

The only constituent that exceeded the ORNL benchmark was mercury, which was found at concentrations of 0.08 to 0.12 mg/kg in the reference soils and 0.12 to 0.25 mg/kg in the soils that contained coal ash. Reference soils had concentrations of manganese, mercury, selenium, vanadium, and zinc that were higher than the EPA Region 4 values. These data suggest that the EPA Region 4 benchmarks are probably. overprotective. For soils that contained coal ash, there were seven EPA benchmark values that were exceeded (arsenic, copper, mercury, manganese, molybdenum, selenium, and vanadium).

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APPENDIX D

Contaminant Migration Analysis and Groundwater Monitoring Results

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1.0 CONTAMINANT MIGRATION ANALYSIS

To study the potential for groundwater contamination, a contaminant migration analysis is necessary to assess the mobility potential of residual contaminants in the vadose zone (unsaturated zone). The analysis is performed using a vadose zone model to account for complex geotechnical and chemical variables including decay processes, infiltration rate, soil properties, vadose zone thickness, migration timeframes, and chemical behavior. Generally, soil screening limits (SSLs) are calculated using these variables. An exceedance of an SSL by a vadose zone contaminant concentration indicates that peak groundwater concentrations may exceed regulatory limits [e.g., Maximum Contaminant Levels (MCLs), USEPA Regional Screening Levels (RSLs) or radiological Preliminary Remedial Goals (PRGs)].

Also, the SSLs are used to identify contaminant migration remedial goal objectives (CM RGOs), if applicable. The CM RGOs are threshold levels of residual contamination in the vadose zone for environmental media (soil, pore-water, and pore-vapor) that will not adversely impact groundwater above regulatory limits. This analysis will evaluate if any residual soil contaminant concentrations from the ash deposits in the wetlands at Dunbarton Bay have the potential to migrate to groundwater and exceed groundwater action levels such as MCLs or USEPA RSLs/PRGs.

1.1 Introduction

The wetlands and Carolina bay are comprised of both cypress and hardwood canopy habitats. The base floor of the wetlands area lies almost entirely at 239.5 feet above mean sea level. Steep ridgelines (up to 82 feet) border portions of the wetland and have subjected it to fluvial forces, effects of which have been amplified by stormwater runoff from industrial areas. Ditches were constructed in the early 1950's to carry clean storm water runoff from P Area and nearby Railroad Yard. The Dunbarton Bay has a long history of disturbance and fragmentation by pre-SRS roads, making natural water flow difficult to decipher. It also appears, not only the Carolina bay, but some of the other bays close to Dunbarton Bay were at some time artificially drained by manmade ditches to control water accumulation in the bays. Based on historical aerial photographs, vegetated riparian zones connect the wetland to the headwaters of Meyers Branch, but it is unknown whether these connections are natural. Based on surface water flow patterns and the nearly straight alignment of the drainage features it appears at least a portion of these are manmade.

The unconsolidated marine and fluvial sediments of the Atlantic Coastal Plain underlying P Area and all of SRS are stratified, heterogeneous sequence of sand, clay, limestone, and gravel layers. In terms of hydrostratigraphy, the uppermost sediments make up the Floridian Aquifer System. In P Area, the Floridian Aquifer System consists of, in ascending order, the Gordon Aquifer, the Gordon Confining Unit, and the Upper Three Runs Aquifer. The Floridian is separated from the lower aquifer units by the Crouch Branch Confining Units, which are a competent aquitard. Generally, groundwater flow direction in both the upper and lower Upper Three Runs Aquifer in P Area diverge with flows toward Steel Creek to the northwest, PAR Pond to the northeast, and Meyers Branch to the southeast.

SRS began early infrastructure development between 1951 and 1955 including the construction of P-Reactor which operated between 1954 and 1991. Similar to each reactor area at SRS, P Area utilized a coal-fired powerhouse to generate steam and electricity, with coal ash (coal combustion products [CCP]) produced as a result of operating the powerhouse boiler. In P Area, this ash was disposed within the P Area Ash Basin via a sluice line. In 2010, during clearing of the 35 acres surrounding the ash basin, ash was discovered outside the ash basin to the north and south-southwest. Additional characterization efforts determined that the ash extended an additional 45 acres in the south-southwest direction into the Dunbarton Bay (a Carolina bay). Ash deposits in the bay and wetlands range from 1 to 3 feet in depth. Since the ash was in a wetland area, the portion of the ash extent was administratively removed from the P-Area Operable Unit and placed in the Steel Creek Integrator Operable Unit (IOU).

Soil and groundwater samples were collected in June 2010 and will used to determine 1) human health and ecological risks, 2) if constituents were still present which exceeded principal threat source material (PTSM) threshold criteria, or 3) if there were still residual soil constituents present that represented a contaminant migration risk to groundwater. This contaminant migration analysis will determine if any residual soil constituents remaining at the wetlands and Dunbarton Bay represent a contaminant migration risk to groundwater.

1.2 Screening Methods

This document describes the screening methods used for identifying contaminant migration constituents of potential concern (CM COPCs) and contaminant migration constituents of concern (CM COCs). The identification of CM COPCs and CM COCs is facilitated by the program *VZCOMML*© V4.0. This program follows the methods described by Rucker 1998a, 2002, and 2007, and the United States Environmental Protection Agency (USEPA) Soil Screening Guidance (USEPA 1996 and USEPA 2000) as described below.

SRS uses Federal Facilities Agreement (FFA) Contaminant Migration Protocols that follow USEPA Soil Screening Guidance. The protocols P.5.1 *Contaminant Migration Constituents of Potential Concern* (WSRC 1998b), P.5.2 *Contaminant Migration Constituents of Concern* (WSRC 2000a), and P.5.3 *Contaminant Migration Remedial Goal Options* [WSRC 2000b (all found in the *Regulatory Document Handbook* ERD-AG-003)] allow for calculation of USEPA default SSLs for a 'Tier I' screen, and SRS site-specific SSLs ($SSL_{T1/2}$) for the 'Tier II' screen. The $SSL_{T1/2}$s (Tier II screen) include numerical terms for chemical/radiological decay, biodegradation, and contaminant travel time which is supported by the *Soil Screening Guidance: Technical Background Documents* (USEPA 1996 and 2000) to account for the physical and chemical complexities often encountered in the subsurface and to more accurately predict risks of exposure via the migration of contaminants to the groundwater pathway. Protocol P.5.1 also applies an upper boundary for evaluation of contaminant migration timeframes to 1,000 years. SSLs are soil concentration thresholds which are back-calculated from drinking water action levels (USEPA 2009) and are used to identify areas of waste units that require (or do not require) further characterization or remediation.

Both the Tier I and Tier II screens include infinite mass source zone and mass-limited source zone algorithms. In reality, the consideration of an infinite source mass is not reasonable, so the mass-limited calculations [default mass-limited SSLs and SRS site-specific mass-limited SSLs ($MLSSLT_{1/2}$s)] consider the entire release of the source mass to groundwater within a 70-year exposure period regardless of the travel time and without sorption factors. This conservative assumption prevents a mass balance error (i.e., releasing more contaminant mass than is actually contained in the source zone) in the calculation which is likely with the use of an infinite source scenario. The equations used to calculate Tier I SSLs and MLSSLs, and Tier II $SSL_{T1/2}$s and $MLSSL_{T1/2}$s are provided below in Section 2.0. The contaminant migration conceptual site model for the Dunbarton Bay is discussed in Section 3.0.

The numerical model called *VZCOMML*© (V.4.0) was developed at SRS to facilitate SSL calculations and Tier I/Tier II soil data screening (WSRC 1999, Rucker 2011). *VZCOMML*© *V4.0* simultaneously calculates the SSLs for inorganic constituents on the Target Analyte List, organics on the Target Compound List, and for specified radionuclides (a total of 221 constituents). *VZCOMML*© compares the waste unit soil concentrations to SSLs and identifies constituents that are Tier I CM COPCs and Tier II CM COCs. *VZCOMML*© has the capability to assign hydraulic functions for different types of soil layers (e.g., source layer, soil layer, or barrier layer [such as concrete or clay]) and different texture classifications (e.g., sand, loamy sand, silty clay, low permeability clay, or concrete) within the soil column. Also, *VZCOMML*© calculates groundwater concentrations and migration times from the input data and automatically compares and evaluates the waste unit concentrations to SSLs to identify constituents that are CM COPCs and CM COCs. Analytes which fail both Tier I and Tier II screening are automatically listed by name in the result module.

The result module of the model contains multiple screening criteria to automatically interpret the numerical data computed during a simulation. The screening criteria are called arguments and are in the form of logic functions embedded in the model code. These logic functions are important to understand because they provide the technical basis for the decisions the software renders. The logic functions are based upon criteria from the SRS Contaminant Migration Protocol and US EPA Soil Screening Guidance. Three logic arguments are associated with the result module:

- Is the groundwater concentration "greater than or equal to" the MCL? In operator form: C_{gw}>=MCL; and
- Is the mean travel time less than or equal to the evaluation time? In operator form: T_t<=T_e; and
- Is the waste site soil concentration greater than or equal to the MLSSL? In operator form: C_t>=MLSSL.

If CM COCs are identified, it is up to the user to evaluate the results and apply professional judgment and other sophisticated modeling approaches and/or knowledge of site conditions and geochemistry to further refine the list of CM COCs. The CM refined COCs (CM RCOCs) include those constituents that are mobile enough to leach to the aquifer within a 1,000 year travel time (per the SRS protocols) and exceed drinking water standards at a receptor well located adjacent to the edge of the waste unit.

In summary, these steps were used to perform this contaminant migration analysis:

1) The analytical soil data was compiled and evaluated for the Dunbarton Bay. The data set was processed to purge all laboratory and field quality assurance/control data and rejected (R qualified) data. The data was further processed to select the maximum concentration for each analyte which was detected from the 2010 Dunbarton Bay soil/ash characterization data set. Only definitive level data was used.

2) The conceptual site model (CSM) was developed and is identified in Figure 2. The hydrogeological parameter inputs and chemical parameters are listed on Tables 1 and 2.

3) The maximum concentration for the detected constituents was used for the total soil concentration (C_t) and loaded in *VZCOMML*© for soil data screening. This is the most conservative approach since the highest concentrations for each analyte found within the wetlands and Dunbarton Bay are used in the analysis.

4) Tier I and Tier II screening was performed using *VZCOMML*© in Simulation 1. Simulation 1 employed a source zone depth of 2 ft of ash as identified in the CSM. A source depth of 2 ft is a conservative because it represents a deeper average ash depth for the wetlands and bay. Figure 1-3 in the CMS/FS, shows only two small areas where the ash depth is measured at 3 ft. Based on Figure 1-3, the majority of the ash area is less than 3 ft in depth. From the elevation contours and assuming equal volumes of ash depth, the average depth of ash would be approximately 1.6 ft as compared to the maximum depth of ash of 3 ft. Therefore, 2 ft of ash is a reasonable and conservative representation. A bottom elevation was determined from a location within the Dunbarton Bay where the deepest depression within the bay could be found (see Section 1.2.1 *Unit Description, Surface Topography*). This location was surveyed for elevation and then compared to the average potentiometric surface across the bay. The depth to groundwater dimension used in the simulation represents the minimum vadose zone thickness anywhere within the bay as it represents the lowest possible elevation within the bay. The depth to groundwater from the bottom of the source zone is the critical dimension for conservatism in the simulation. Adding an additional 1 ft of source depth would not change the result of the analysis because the elevation datum used in the simulation was the lowest elevation within the bay. Those constituents that exceeded Tier I SSLs were retained as CM COPCs and automatically subjected to Tier II screening by the model. The constituents that exceeded $SSL_{T1/2}$s and predicted to reach the water table within 1,000 years were retained as CM COCs; however, there were no CM-COCs identified in Simulation 1.

5) Those constituents identified as CM-COCs from Step #4 would be tested again during a CM-COC refinement step in Simulation 2. Simulation 2 would use a site-specific source zone depth based on sample elevations for each analyte identified as a CM COC and a reasonable maximum exposure (RME) concentration would be calculated for each CM COC (instead of using the maximum concentration). However, since there were no CM-COCs identified in Step #4; Simulation 2 did not need to be performed.

6) Screening-level CM RGOs are calculated for each CM RCOC (generally, the CM RGO is the highest Tier II SSL concentration). Since no CM RCOCs were identified, there are no CM RGOs calculated for the Dunbarton Bay.

2.0 Soil Screening Equations

As previously mentioned, the equations used by *VZCOMML*© are consistent with USEPA Soil Screening Guidance and SRS Contaminant Migration Protocols. The diagram that illustrates the conceptual framework of the model and vadose zone for *VZCOMML*© is provided in Figure 1. Significant assumptions of the model, which is consistent with USEPA soil screening guidance include: 1) a receptor drinking water well at the downgradient edge of the source zone with the well screen located in the plume, 2) linear equilibrium isotherms are used rather than exponential isotherms, 3) uniformly distributed contamination in the subsurface; and 4) instantaneous equilibrium partitioning within soil, vapor, and liquid phases. Generally, the source zone thickness represents the vertical extent of contamination. For each constituent the source concentration is the maximum detected concentration regardless of sample location. Layer 1 is the source zone and layer 2 is the vadose zone beneath the source zone and is used to simulate the soil heterogeneity in the soil column. These layers can accommodate different hydraulic functions, soil textures, properties, and layer thicknesses for up to 5 soil layers. The aquifer layer represents the shallowest (uppermost) water table aquifer (Figure 2). Following is a discussion of the equations used by *VZCOMML*© for the soil screening process.

2.1 Dilution Attenuation Factor

The dilution attenuation factor (DAF) represents leachate dilution in the water table aquifer. The DAF calculation assumes that the aquifer is unconfined, unconsolidated, isotropic and homogeneous. The minimum DAF is 1, which indicates no dilution occurs in the aquifer. The USEPA recommends a default DAF of 20 for sites up to 0.5 acre whenever site-specific data are not available (USEPA 1996). The DAF (dimensionless) is calculated as follows:

$$DAF = 1 + \frac{K_a \cdot i \cdot d}{I \cdot L}$$

where;

K_a = saturated zone (aquifer) hydraulic conductivity (ft/yr),

i = saturated zone (aquifer) hydraulic gradient (ft/ft),

I = infiltration rate through vadose zone (ft/yr),

L = length of the source (parallel to groundwater flow) (ft),

d_a = measured saturated zone (aquifer) thickness (ft),

d_i = calculated mixing zone depth (ft),

and d = mixing zone depth (minimum of d_i and d_a) (ft).

If the input infiltration rate through the vadose zone is greater than any of the individual vadose zone layer saturated hydraulic conductivities, then the infiltration rate is adjusted to the maximum of the individual vadose zone layer saturated hydraulic conductivities. The mixing zone depth (d) is calculated as follows:

$$d_i = \sqrt{0.0112 \cdot L^2} + d_a(1 - e^{(-L \cdot I/(K_a \cdot i \cdot d_a))})$$

The d_i calculated value cannot exceed the actual aquifer thickness. Therefore, the mixing zone depth is the minimum of d_i or d_a.

2.2 Soil Partitioning

The SSL soil concentration is back-calculated by two methods: 1) an infinite source equation and, 2) a finite source equation. The Tier I SSL assumes an infinite source and uses a linear equilibrium soil-water partitioning isotherm. The Tier I SSL is used for organic contaminants and mercury (with vapor phase) as follows:

$$Tier1SSL = \frac{MCL}{1000} \cdot DAF \cdot \left(K_d + \frac{(\theta_w + \theta_a \cdot H)}{\rho_b} \right)$$

where;

MCL = water-phase concentration limit standard (i.e., MCL or RSL) (µg/L),

K_d = soil-water partitioning coefficient (L/kg),

θ_w = water-filled soil porosity (fraction),

θ_a = air-filled soil porosity (fraction), $\theta_a = n_t - \theta_w$

n_t = total porosity (fraction),

H = Henry's Law constant (dimensionless),

ρ_b = dry soil bulk density (kg/L).

The Tier I SSL equation for inorganic contaminants (without vapor phase) is;

$$Tier1SSL = \frac{MCL}{1000} \cdot DAF \cdot \left(K_d + \frac{\theta_w}{\rho_b}\right)$$

and for radionuclides;

$$Tier1SSL = DefaultSSL \cdot \left(\frac{\lambda t}{1 - e^{(-\lambda t)}}\right)$$

where;

t = time of exposure (EPA default value of 30 years)

λ = decay rate constant [ln(2)/$t_{1/2}$ yr]

To prevent the mass-balance violations inherent in the infinite source equation, USEPA developed the mass-limited soil screening limit (Tier I MLSSL, mg/kg) for organics and inorganics as follows:

$$TierIMLSSL = \frac{MCL}{1000} \cdot DAF \cdot \frac{(I \cdot ED)}{(\rho_b \cdot d_s)}$$

where;

ED = exposure duration in years (USEPA default value of 70 years),

d_s = average source thickness (ft).

The mass-limited soil screening limit equation for radionuclides is:

$$TierIMLSSL = DefaultMLSSL \cdot \left(\frac{\lambda t}{1 - e^{(-\lambda t)}}\right)$$

For organic constituents, the soil-water partitioning coefficient (K_d) (L/kg) is defined by:

$$K_d = f_{oc} \cdot K_{oc}$$

where;

f_{oc} = soil organic carbon content as mass fraction (fraction),

K_{oc} = organic carbon partitioning coefficient (L/kg).

For metals or radionuclides, the K_d is taken from literature and is dependent on the chemical form that exists and the geochemical environment at each site. Normally, the K_d is derived from laboratory column studies.

The water-filled porosity (θ_w) is based on a weighted average for all vadose zone layers and calculated as follows:

$$\theta_w = \sum_{i=1}^{n} \left(\frac{T_{hi}}{T_c} \right) \cdot \theta_{wi}$$

where;

T_{hi} = layer *i* vertical thickness (ft),

T_c = total depth of soil column (ft), = (d_s + L_v)

L_v = length from the bottom of the source zone to the top of the water table (ft),

θ_{wi} = layer *i* water-filled soil porosity (fraction).

The soil texture is determined for the different layers or soil types observed in the vadose zone, and the soil layer parameters are used to calculate the volumetric water content as follows:

$$\theta_{wi} = n_{ti} \left(\frac{I}{K_{si}} \right)^{\left(\frac{1}{(2b_i+3)} \right)}$$

where;

n_{ti} = layer *i* total porosity (fraction),

K_{si} = layer *i* Clapp and Hornberger "K" parameter based on soil texture (ft/yr),

b_i = layer *i* Clapp and Hornberger "b" parameter based on soil texture (dimensionless).

The vadose zone total porosity (n_t, fraction) and vadose zone effective porosity (n_e, fraction) are both based on a weighted average for all vadose zone layers and calculated as follows:

$$n_t = \sum_{i=1}^{n} \left(\frac{T_{hi}}{T_c} \right) \cdot n_{ti}$$

$$n_e = \sum_{i=1}^{n} \left(\frac{T_{hi}}{T_c} \right) \cdot n_{ei}$$

where;

n_{ei} = layer *i* effective porosity (fraction).

The effective moisture content θ_e (fraction) is a weighted average for all vadose zone layers as follows;

$$\theta_e = \sum_{i=1}^{n} \left(\frac{T_{hi}}{T_c} \right) \cdot \theta_{ei}$$

where;

θ_{ei} = layer *i* effective moisture content (fraction).

2.3 Mean Travel Time

The mean travel time (T_{Mean} or T_t, yr) is the retarded time for a contaminant to migrate through the vadose zone (below the source) to the aquifer and is calculated in VZCOMML as follows:

$$T_{Mean} = \frac{L_v \cdot R}{V_s}$$

The retardation coefficient (R, dimensionless) is calculated as:

$$R = 1 + \frac{(K_d \cdot \rho_\beta)}{\theta_s}$$

The mean pore water velocity in the vadose zone (V_s, ft/yr) is a weighted average calculated by:

$$V_s = \sum_{i=1}^{n} \left(\frac{T_{ti}}{T_t}\right) \cdot V_{si}$$

where;

V_{si} = layer *i* mean pore water velocity (ft/yr),

T_{ti} = layer *i* mean travel time (yr),

T_t = Travel Time (yr)

By applying Darcy's Law in the unsaturated zone and assuming steady-state conditions;

$$V_{si} = \frac{I}{\theta_{wi}}$$

2.4 Incorporating Decay

To account for the radioactive decay, chemical degradation, hydrolysis, or biodegradation of constituents and also for redistribution of contaminant mass in the vadose zone, Tier II SSL $_{T1/2}$ and Tier II $MLSSL_{T1/2}$ are adjusted by using first-order differential decay terms as follows for the infinite source equations for organics and inorganics with vapor-phase:

$$SSL_{t1/2} = C_w(MCL) \cdot DAF \cdot \left(K_d + \frac{\theta_w + \theta_a \cdot H}{\rho_\beta}\right) \cdot \left(\frac{1}{e^{(-\lambda T_{Mean})}}\right) \cdot \left(\frac{T_c}{d_s}\right)\left[\frac{mg}{kg}\right]$$

The infinite source equation for radionuclides is:

$$SSL_{t1/2} = C_w(MCL) \cdot (0.001) \cdot DAF \cdot \left(K_d + \frac{\theta_w}{\rho_\beta}\right) \cdot \left(\frac{\lambda t}{1 - e^{(-\lambda t)}}\right) \cdot \left(\frac{1}{e^{(-\lambda T_{Mean})}}\right) \cdot \left(\frac{T_c}{d_s}\right)\left[\frac{pCi}{g}\right]$$

The mass balance equation for organics and inorganics is:

$$MLSSL_{t1/2} = C_w(MCL) \cdot DAF \cdot \left(\frac{I \cdot ED}{\rho_\beta \cdot d_s}\right) \cdot \left(\frac{1}{e^{(-\lambda ED)}}\right)\left[\frac{mg}{kg}\right]$$

The mass balance equation for radionuclides is:

$$MLSSL_{t1/2} = C_w(MCL) \cdot (0.001) \cdot DAF \cdot \left(\frac{I \cdot ED}{\rho_\beta \cdot d_s}\right) \cdot \left(\frac{\lambda t}{1 - e^{(-\lambda t)}}\right) \cdot \left(\frac{1}{e^{(-\lambda ED)}}\right)\left[\frac{pCi}{g}\right]$$

A half-life for a chemical compound is largely determined from literature sources. Because there is usually variability of the reported half-life of a chemical compound e.g, aerobic and anaerobic rates, the most conservative (longest) half-life is selected as the rate constant in the equations. The rate constants used in the VZCOMML© model are primarily derived from the publications of P. H. Howard, et al. and D. McKay, et al, but other references may also be used such as USEPA's EPI Suite software and USEPA's Human Health Risk Assessment Parameters database. The half-life for all inorganic constituents (metallic) is considered to be infinite.

VZCOMML© assumes equilibration, mass redistribution, and conservation of mass in the source zone between phases (i.e., volatilized, dissolved, or sorbed) and throughout the entire vadose zone volume. This results in 'more realistic' SSLs which accounts for vadose zone thickness, travel time, and chemical behavior in the subsurface.

The *VZCOMML©* screening decision logic for a constituent 'fails' if; 1) the mean travel time (T_{Mean}) through the vadose zone is less than 1,000 years, and 2) the source concentration exceeds the Tier II MLSSL and 3) the groundwater concentration exceeds an action level (i.e., the calculated concentration in groundwater would exceed the regulatory limit; MCLs or RSLs/PRGs). In this case, the constituent would be retained as a CM COC and subject to further CM COC refinement steps.

2.5 Saturation Concentration

For organic (non-radioactive) constituents, the saturation concentration (C_{sat}) (mg/kg) is calculated from the solubility constant in water (S) (mg/L) as follows:

$$C_{sat} = \frac{S}{\rho_\beta} \cdot \left(K_d \cdot \rho_\beta + \theta_w + H \cdot \theta_a\right)$$

The C_{sat} is a theoretical concentration that represents a pure non-aqueous phase liquid (NAPL) or solid threshold concentration in soil. The C_{sat} is compared to the detected concentration to predict if a NAPL phase compound is present in the soil.

2.6 Groundwater Concentration

The concentration of constituents in groundwater in the water table aquifer is directly calculated by *VZCOMML©* for comparison to groundwater regulatory limits. The groundwater concentration (C_{gw}, µg/L) is calculated as follows (Rucker 2011):

- Infinite source equation for groundwater for organic and inorganic contaminants with vapor phase;

$$C_w = \frac{\left(\frac{C_t}{DAF}\right)}{\left(K_d + \frac{\theta_w + \theta_a \cdot H}{\rho_\beta}\right)} \cdot \left(\frac{e^{(-\lambda T_{Mean})}}{1}\right) \cdot \left(\frac{d_s}{T_c}\right)\left[\frac{mg}{L}\right]$$

T_c = Thickness of soil column (feet)

- Infinite source equation for groundwater for radionuclides:

$$C_w = \frac{\left(\frac{C_t \cdot 1000\left[\frac{g}{kg}\right]}{DAF}\right)}{\left(K_d + \frac{\theta_w}{\rho_\beta}\right)} \cdot \left(\frac{\lambda t}{1 - e^{(-\lambda t)}}\right) \cdot \left(\frac{e^{(-\lambda T_{Mean})}}{1}\right) \cdot \left(\frac{d_s}{T_c}\right)\left[\frac{pCi}{L}\right]$$

VZCOMML© assumes equilibration, redistribution, and conservation of mass of the source between phases (i.e., volatilized, dissolved, or sorbed) and distribution throughout the entire vadose zone volume. The concentration of constituents in groundwater in the water table aquifer is directly calculated by *VZCOMML©* for comparison to groundwater regulatory limits or standards.

3.0 CONCEPTUAL MODELS

The conceptual diagram for the VZCOMML© V4.0 software is shown in Figure 1. The site conceptual model for the Dunbarton Bay is illustrated on Figure 2. The water table surface is ~8 feet beneath the ground surface near the deepest portion of Dunbarton Bay and the soil column consists of clay layers. Rather than demarcate each thin clay layer, the cumulative soil thicknesses in the vadose zone were used as separate layers in the model and correspond with the source zone (layer 1) and the uncontaminated soil layer beneath (layer 2) as in Figure 2.

4.0 RESULTS

The purpose for this contaminant migration analysis was to assess the migration potential of the residual contaminants using the characterization data collected at Dunbarton Bay. This contaminant migration analysis approach is conservative as the maximum concentrations of the constituents were used in this analysis and a receptor drinking water well was located adjacent to the boundary of the bay. Additionally, the calculated DAF for Simulation 1 was 1.49 which is a small DAF because the lowest possible DAF is 1 which represents no dilution by mixing in the aquifer.

Tier I Analysis

The Tier I analysis identified as arsenic, barium, cobalt, iron, manganese, and thallium and radium-226 as CM-COPCs.

Tier II Analysis

The Tier II analysis did not identify any analyte as a CM-COC. Therefore, there are no analytes existing at Dunbarton Bay which have the potential to migrate to the aquifer and exceed an MCL, RSL or PRG.

5.0 GROUNDWATER MONITORING RESULTS

Groundwater samples were collected from various depths beneath the wetlands and Dunbarton Bay and compared to an MCL, RSL, or PRG (Table 2). A total of 13 monitoring wells were used to sample groundwater at various depths below the wetland and Dunbarton Bay. All wells were sampled at least 7 times and others as many as 38 times from April 2011 until February 2012. Groundwater samples were collected from 9 ft MSL to 207 ft MSL beneath and near the Dunbarton Bay. The large number of samples collected provides for statistical stability and representiveness in monitoring trends of groundwater quality. See Table below.

The table below provides a list of the wells, their coordinates, and screen zones that were used to collect the groundwater samples. All monitoring wells were installed and constructed according to in the 3Q-1 Manual and SCDHEC requirements.

Screening was conducted for all maximum detected GW concentrations and compared to either the MCLs or tap water RSLs. GW samples were collected and only one detection of gross alpha and one detection of beryllium were found to exceed an MCL, one time each. Both analytes are anomalous detections from a single well - RGW-7C. Beryllium was detected once at 10.6 μg/L (MCL = 4.0 μg/L) in April 2011 but thereafter was only detected at less than 1.0 μg/L in four successive samples or 1 out of 5 times. Gross alpha was similarly detected once at 18.2 pCi/L (MCL = 15.0 pCi/L) in April 2011, but thereafter, was only detected at less than 2.7 pCi/L or not detected in the next four sampling events, or 1 out of 5 times. Therefore, there has only been one detection of each analyte above its respective drinking water standard, with four samples collected subsequently, without exceeding a drinking water standard. RGW-7C is side-gradient to the GW flow in the wetlands and the screen zone is too deep to be impacted by the wetlands. Deeper wells closer to the wetlands did not have these detections. The fact there were only two analytes to exceed a drinking water standard provides a converging line of evidence that a conservative contaminant migration analysis has accurately predicted that none of the soil analytes would migrate to GW and exceed an MCL, RSL, or PRG.

6.0 CM RGOS

Since CM RCOCs are not identified for Dunbarton Bay, CM-RGOs have not been calculated.

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FIGURES AND TABLES

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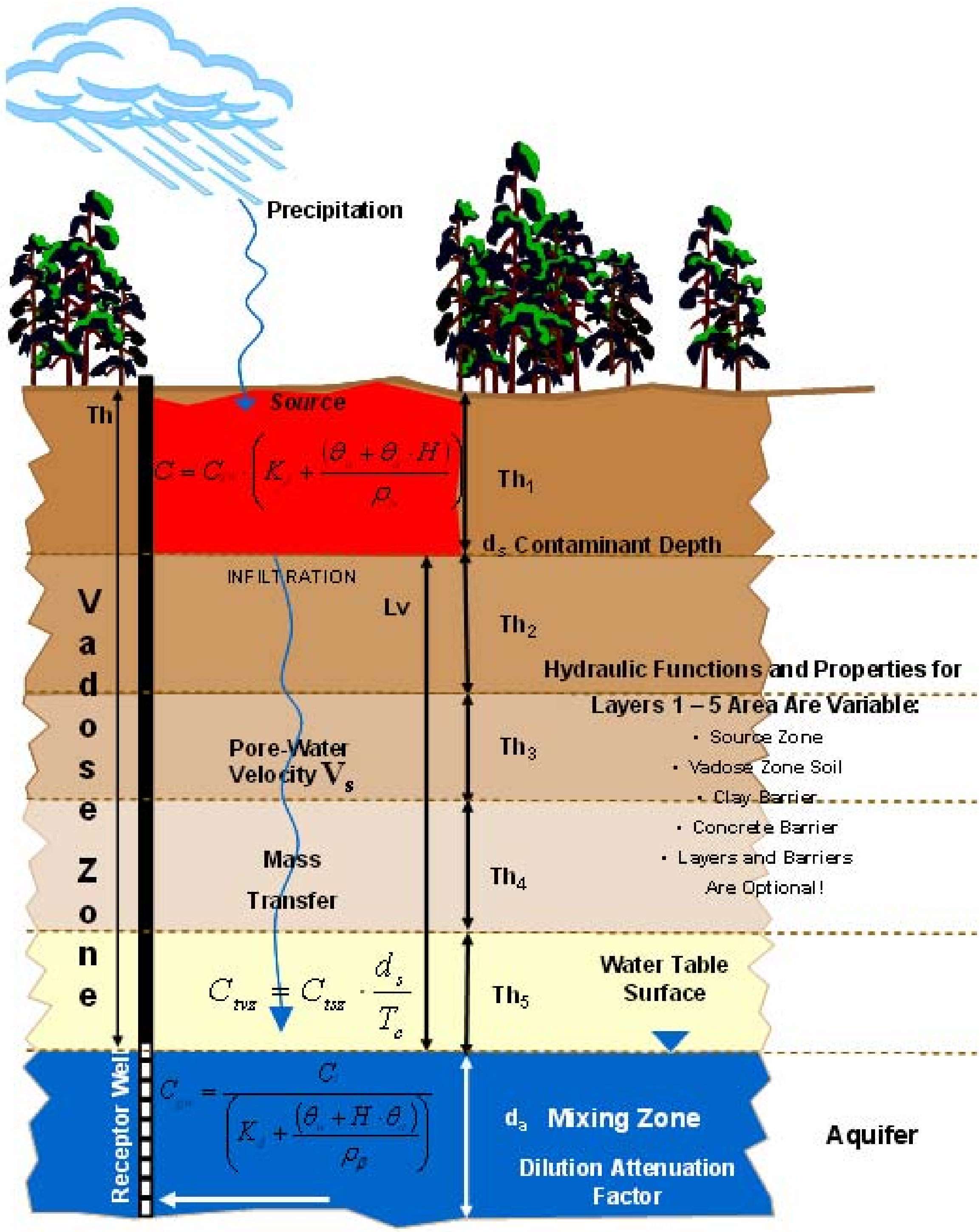
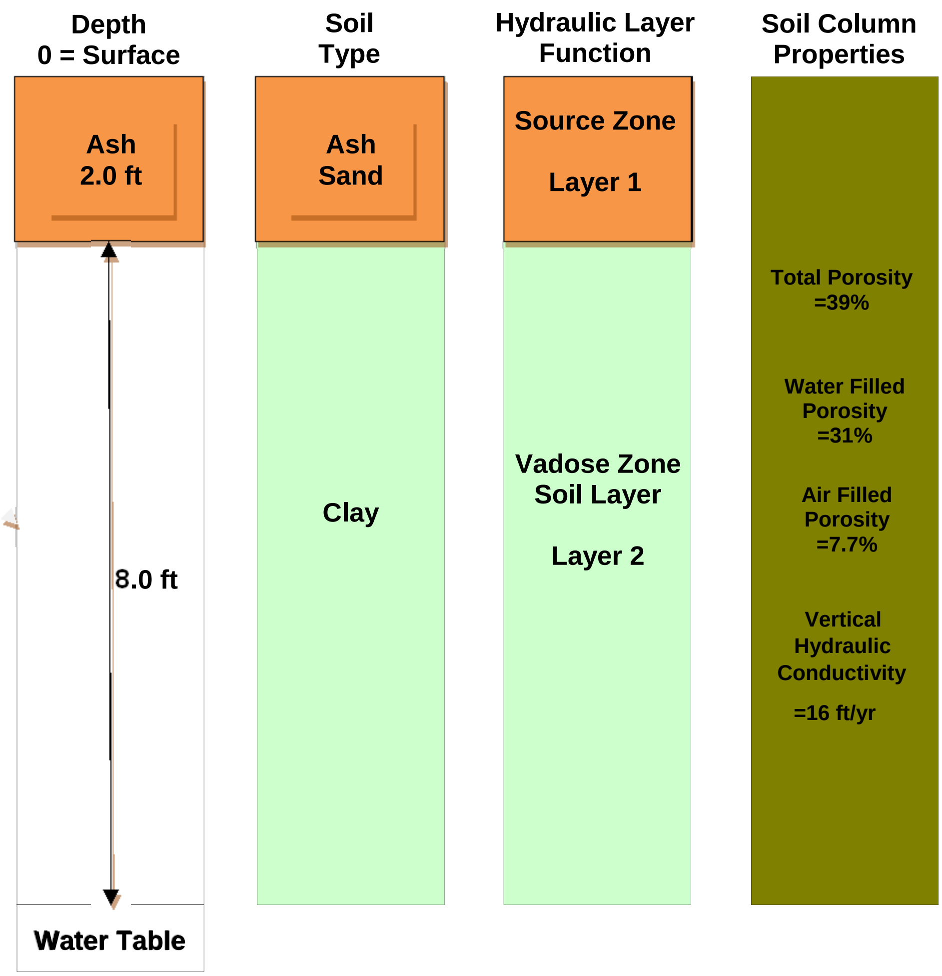


Figure 1. **VZCOMML© Contamination Migration Modeling Conceptual Diagram**



Soil Column Data Summary		
Input Parameters	**Value**	**Units**
Depth of Contamination	2	ds [feet]
Bottom of Source Zone to Top of Water Table	8	Lv [feet]
Total Depth Soil Column	10	Tc [feet]
Water-filled porosity	31.23%	θw [%] wt avg
Air-filled porosity	7.77%	θa [%] wt avg
Effective moisture content	25.84%	θe [%] wt avg
Total Porosity	39.00%	nt [%] wt avg
Unretarded Pore-water Velocity from Source Zone Bottom to Aquifer	2.93	[ft/yr]
Unretarded Travel Time from Bottom of Source Zone to Aquifer	2.73	[yrs]
Unretarded Pore-water Velocity for Entire Soil Column	3.20E+00	Vs [ft/year] wt avg
Unretarded Travel Time for Entire Soil Column	3.12	Tt [yrs]

Figure 2 **Wetlands at Dunbarton Bay Conceptual Site Model**

Table 1. Monitoring Wells Sampled at Dunbarton Bay

Well ID	Latitude	Longitude	Screen Top *(ft MSL)*	Screen Bottom *(ft MSL)*	Ground Elevation *(ft MSL)*	Reference Elevation *(ft MSL)*	Total Depth *(ft)*	Diameter *(inch)*	Mat-erial	Completion Date
PAS001C	33.21998884	-81.57239621	167.29	157.29	263.29	265.78	117	2	PVC	13-Jun-11
PAS001D	33.21996379	-81.57242015	203.32	193.32	263.32	265.65	72.25	2	PVC	13-Jun-11
PAS002D	33.21799958	-81.56308372	195.64	185.64	242.64	244.96	60	2	PVC	14-Jun-11
PAS003D	33.21205245	-81.56236395	182.35	172.35	240.35	242.84	70.17	2	PVC	15-Jun-11
PGW-05A	33.22056713	-81.55901139	9.79	-0.23	243.48	245.63	246.21	2	PVC	6-May-03
PGW-05B	33.22058487	-81.55903181	60.78	50.75	243.45	245.59	195.2	2	PVC	6-May-03
PGW-05C	33.22060173	-81.55905144	147.42	137.35	243.42	245.56	108.57	2	PVC	7-May-03
PGW-10B	33.21143322	-81.56920246	77.51	67.49	253.51	255.86	188.52	2	PVC	8-May-03
PGW-10C	33.2114249	-81.56926663	152.75	142.74	253.75	256.08	113.51	2	PVC	28-Jan-03
PGW-10CU	33.21145248	-81.56924248	198.64	188.64	253.64	255.91	67.27	2	PVC	30-Sep-03
PGW-10DL	33.21142957	-81.56923703	207.6	197.6	253.6	255.9	58.5	2	PVC	28-Jan-03
RGW 7C	33.21296	-81.5782	93.85	83.85	295.85	298.35	222	2	PVC	29-Jul-98
RGW 7D	33.21299	-81.5782	175.45	165.45	295.45	297.95	138	2	PVC	29-Jul-98

Table 2. Maximum Groundwater Concentrations Screened Against MCLs/RSLs

Analyte Name	Total Samples	# Detects	Mean DL	Mean Detection	Minimum Detection	Maximum Detection	MCL/ RSL	Max >MCL /RSL?	# Samples Exceeding MCL/RSL
Arsenic	52	3	2.54E+01	1.53E+00	1.30E+00	1.90E+00	1.00E+01	No	0
Barium	52	52	8.92E+00	3.55E+01	3.84E+00	1.73E+02	2.00E+03	No	0
Beryllium	52	15	6.92E-01	1.09E+00	1.03E-01	1.06E+01	4.00E+00	Yes	1
Cadmium	32	7	5.00E-01	1.56E-01	1.30E-01	2.00E-01	5.00E+00	No	0
Chromium	32	3	1.00E+01	4.20E+00	3.50E+00	5.40E+00	1.00E+02	No	0
Cobalt	52	31	3.46E+00	9.68E-01	2.70E-01	4.30E+00	1.00E+01	No	0
Copper	52	36	2.54E+00	1.08E+00	5.02E-01	3.40E+00	1.30E+03	No	0
Gross Alpha	52	25	3.96E+00	2.87E+00	6.20E-01	1.82E+01	1.50E+01	Yes	1
Iron	52	37	6.92E+01	8.03E+02	1.09E+01	5.79E+03	2.60E+04	No	0
Lead	52	36	3.77E+00	1.05E+00	2.00E-01	6.00E+00	1.50E+01	No	0
Manganese	52	48	5.08E+00	1.58E+01	3.00E-01	7.16E+01	8.80E+02	No	0
Mercury	10	0	2.00E-01	ND	ND	ND	ND	NA	NA
Nonvolatile Beta	52	21	5.37E+00	2.89E+00	8.40E-01	1.80E+01	NA	NA	NA
Selenium	52	0	8.85E+00	ND	ND	ND	ND	NA	NA
Silver	32	6	2.00E+00	4.12E-01	1.30E-01	1.40E+00	1.80E+02	No	0
Tetrachloroethylene (PCE)	10	0	5.00E-01	ND	ND	ND	5.00E+00	NA	NA
Thallium	48	18	1.58E+00	1.29E+00	1.57E-01	2.10E+00	5.00E+00	No	0
Trichloroethylene (TCE)	10	0	5.00E-01	ND	ND	ND	5.00E+00	NA	NA
Tritium	10	7	5.41E-01	8.07E-01	1.49E-01	2.01E+00	2.00E+01	No	0
Zinc	52	19	1.96E+01	9.08E+00	3.23E+00	1.69E+01	1.10E+04	No	0

Table 2 Notes:

1) MCL = maximum contaminant level per USEPA current Drinking Water Regulations: http://www.epa.gov/safewater/standard/index.html. Note that radionuclides are covered under the MCL of 4 mrem/year for beta and photon radioactivity from man-made radionuclides in drinking water. The MCL is the average concentration of the radionuclide that would yield 4 mrem/year (the sum of the annual dose from all beta and photon emitters present must not exceed 4 mrem/yr).
2) RSL = risk-based regional screening level for chemical contaminants (last updated Novermber 2011); http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm
3) PRG = risk-based preliminary remediation goal for radiological constituents for tap water media (last updated August 2010); http://epa-prg-ornl.gov/radionuclides
4) Half-life values for radionuclides are compiled from *Nuclides and Isotopes*, Lockheed Martin, 2002; www.chartofthenuclides.com
5) *From G. G. Rucker 2001 Technical Memorandum ERTEC-2001-0001 and calculation note Q-CLC-B-00019

Table 3. Input Values for VZCOMML V4.0 Model

Input Values	Units	Parameter	Reference
338	Feet	(L) Source length parallel to groundwater flow	SGCP 2010
1.0	Feet	(I) Infiltration rate through vadose zone	GeoTrans 2003
100	Feet/year	(K_a) Aquifer saturated horizontal hydraulic conductivity	SGCP 2010
83	Feet	(d_a) Aquifer thickness	SGCP 2010
0.02	Feet/feet	(i) Horizontal hydraulic gradient	Measured value
2.0	Feet	(Th_1) Source zone layer 1 thickness	SGCP 2010
8.0	Feet	(Th_2) Soil layer 2 thickness	Site-specific measurement
Source Zone	Not Applicable	Layer 1 hydraulic function	Not applicable
Soil Layer	Not Applicable	Layer 2 hydraulic function	Not applicable
Clay	Not Applicable	Soil Classification	Not applicable
0.38	Decimal fraction	(n_t) Total porosity	NUREG 1997
0.311	Decimal fraction	(n_e) Effective porosity	NUREG 1997
16.0	Feet/year	(K_s) Saturated vertical hydraulic conductivity	USEPA 1996
70.0	Years	(ED) Exposure duration	USEPA 1996
1,000	Years	(T_e) Evaluation time	WSRC 1998b
1.7	Kilograms/Liter	(ρ_β) Dry bulk density	Rucker 1998b
0.002	Decimal fraction	(f_{oc}) Fraction organic carbon	Rucker 1999
1.49	Unitless	Dilution Attenuation Factor	Calculated

Table 4. Chemical and Other Input Parameters used for Screening

Analyte	K_{oc} *(L/kg)*	K_d *(L/kg)*	Half-life *(yrs)*	Henry's Law Constant	Solubility *(mg/L)*	Standard *(μg/ or pCi/L)*	
Aluminum	NA	1.50E+03	Infinite	None	None	1.60E+04	RSL
Arsenic	NA	2.68E+02	Infinite	None	None	1.00E+01	MCL
Barium	NA	4.10E+01	Infinite	None	None	2.00E+03	MCL
Beryllium compounds	NA	7.90E+02	Infinite	None	None	4.00E+00	MCL
Cadmium	NA	7.50E+01	Infinite	None	None	5.00E+00	MCL
Chromium	NA	1.80E+06	Infinite	None	None	1.00E+02	MCL
Cobalt	NA	1.60E+02	Infinite	None	None	4.70E+00	RSL
Copper, Total	NA	6.70E+01	Infinite	None	None	1.30E+03	MCL
Iron	NA	2.20E+02	Infinite	None	None	1.10E+04	RSL
Lead and compounds	NA	5.00E+03	Infinite	None	None	1.50E+01	MCL
Manganese	NA	2.68E+02	Infinite	None	None	3.20E+02	RSL
Mercury elemental	NA	5.20E+01	Infinite	None	None	2.00E+00	MCL
Nickel soluble salts	NA	6.50E+01	Infinite	None	None	3.00E+02	RSL
Selenium	NA	1.00E+03	Infinite	None	None	5.00E+01	MCL
Silver	NA	9.00E+01	Infinite	None	None	7.10E+01	RSL
Thallium Soluble Salts	NA	8.00E+01	Infinite	None	None	2.00E+00	MCL
Vanadium and compounds	NA	1.00E+03	Infinite	None	None	7.80E+01	RSL
Zinc and compounds	NA	1.30E+03	Infinite	None	None	4.70E+03	RSL
Actinium-228	NA	4.50E+02	7.00E-04	None	None	2.66E+01	PRG
Cesium-137	NA	5.00E+02	3.02E+01	None	None	2.00E+02	MCL
Potassium-40	NA	7.5E+01	1.28E+09	None	None	2.14E+00	PRG
Radium-226	NA	1.00E+02	1.60E+03	None	None	5.00E+00	MCL
Radium-228	NA	1.00E+02	5.75E+00	None	None	5.00E+00	MCL
Thorium-228	NA	2.00E+03	1.91E+00	None	None	1.50E+00	MCL
Thorium-230	NA	2.00E+03	7.70E+04	None	None	1.50E+00	MCL
Thorium-232	NA	2.00E+03	1.41E+10	None	None	1.50E+00	MCL
Uranium-234	NA	3.00E+02	2.45E+05	None	None	1.00E+01	MCL*
Uranium-235	NA	3.00E+02	7.04E+08	None	None	5.00E-01	MCL*
Uranium-238	NA	3.00E+02	4.47E+09	None	None	1.00E+01	MCL*

Table 5 Tier 1 Metallic Analytes Screening Results for the Dunbarton Bay

ANALYTE	SOURCE ZONE CONCENTRATION Ct (mg/kg)	Tier I SOURCE-SPECIFIC SSL (mg/kg)	Tier I MASS LIMIT SSL (mg/kg)	ANALYTES >=SSL (mg/kg)
Aluminum	6.97E+03	3.58E+04	4.91E+02	
Antimony (metallic)		3.58E+01	1.84E-01	
Arsenic, Inorganic	3.36E+01	4.00E+00	3.07E-01	Arsenic, Inorganic
Barium	1.44E+02	1.23E+02	6.14E+01	Barium
Beryllium and compounds	2.08E+00	4.71E+00	1.23E-01	
Cadmium	2.24E-01	5.61E-01	1.53E-01	
Calcium		NA	NA	NA
Chromium, Total	1.54E+01	2.68E+05	3.07E+00	
Cobalt	7.60E+00	1.12E+00	1.44E-01	Cobalt
Copper, Total	5.58E+01	1.30E+02	3.99E+01	
Cyanide (CN-)		3.01E+00	6.14E+00	
Iron	1.42E+04	3.61E+03	3.38E+02	Iron
Lead and compounds	1.36E+01	1.12E+02	4.60E-01	
Magnesium	3.60E+02	NA	NA	NA
Manganese	3.54E+02	1.28E+02	9.82E+00	Manganese
Mercury (elemental)	7.73E-02	1.56E-01	6.14E-02	
Nickel Soluble Salts	1.26E+01	2.92E+01	9.21E+00	
Potassium		NA	NA	NA
Selenium	5.44E+00	7.46E+01	1.53E+00	
Silver	2.04E-01	9.55E+00	2.18E+00	
Sodium, total recoverable		NA	NA	NA
Thallium Soluble Salts	3.67E+00	2.39E-01	6.14E-02	Thallium Soluble Salts
Uranium (elemental)		1.34E+01	9.21E-01	
Vanadium and compounds	2.58E+01	1.16E+02	2.39E+00	
Zinc and compounds	5.50E+01	9.11E+03	1.44E+02	

Table 6 Tier I Radionuclide Screening Results for the Wetlands at Dunbarton Bay

ANALYTE	SOURCE ZONE CONCENTRATION (pCi/g)	Tier I SOURCE-SPECIFIC SSL (pCi/g)	Tier I MASS LIMIT SSL (pCi/g)	ANALYTES >=SSL (pCi/g)
Actinium-228	2.50E+00	5.30E+05	2.43E+04	
Americium-241		2.30E+00	4.72E-01	
Americium-243		2.24E+00	4.61E-01	
Antimony-124		4.51E+04	2.32E+02	
Antimony-125		1.34E+04	6.92E+01	
Carbon-14		1.65E+02	6.15E+01	
Cesium-134		6.02E+02	2.48E+01	
Cesium-137	5.19E+00	2.06E+02	8.49E+00	
Cobalt-57		4.25E+02	8.60E+02	
Cobalt-60		6.11E+00	1.23E+01	
Curium-242		3.23E+03	2.14E+01	
Curium-243/244		9.77E+01	6.49E-01	
Curium-245/246		6.94E+01	4.61E-01	
Curium-247		6.93E+01	4.60E-01	
Europium-152		4.28E+01	3.60E+00	
Europium-154		1.91E+02	1.60E+01	
Europium-155		9.34E+02	7.84E+01	
Iodine-129		5.64E-03	3.07E-02	
Lead-212		1.48E+04	1.13E+03	
Manganese-54		5.44E+02	2.23E+02	
Neptunium-237		7.87E-01	4.60E-01	
Neptunium-239		5.03E+04	2.95E+04	
Nickel-59		1.15E+02	9.21E+00	
Nickel-63		2.12E+01	1.70E+00	
Niobium-94		5.59E+00	2.09E-01	
Plutonium-238		1.48E+02	5.17E-01	
Plutonium-239/240		1.32E+02	4.61E-01	
Potassium-40	1.64E+01	2.71E+01	6.57E-02	
Promethium-147		1.71E+03	1.46E+02	
Radium-226	2.38E+00	7.52E-01	1.54E-01	Radium-226
Radium-228	2.50E+00	2.78E+00	5.70E-01	
Sodium-22		4.78E+02	9.82E+01	
Strontium-90		1.37E-01	3.46E-01	
Technetium-99		3.81E-01	2.76E+01	
Thorium-228	2.21E+00	4.87E+02	5.01E+00	
Thorium-230	2.71E+00	4.47E+01	4.61E-01	
Thorium-232	2.29E+00	4.47E+01	4.60E-01	
Uranium-233/234	2.40E+00	4.48E+00	3.07E-01	
Uranium-235	1.76E-01	2.24E-01	1.53E-02	
Uranium-238	2.51E+00	4.48E+00	3.07E-01	
Zinc-65		8.66E+02	2.87E+02	
Zirconium-95		2.13E+04	7.29E+02	

Table 7 Tier II Metallic Analytes Screening Module Results for the Wetlands at Dunbarton Bay

Metallic Inorganic Analytes	Retardation[27] R (Unitless)	Mean Travel Time[28] T_{Mean} (years)	Groundwater[31] Concentration C_{gw} in Aquifer (µg/L)	Action Level MCL or SL (µg/L)	Analytes Greater Than MCL/SL/MLSSL and Less Than Evaluation Time (T_e)	Tier II[29] $SSL_{T1/2}$ SSL (mg/kg)	Tier I[25] Default MLSSL (mg/kg)	Tier I[23] Default SSL (mg/kg)
Aluminum	9.87E+03	2.47E+04	6.23E+02	1.60E+04		1.79E+05	4.91E+02	3.58E+04
Antimony (metallic)	2.63E+04	6.57E+04		6.00E+00		1.79E+02	1.84E-01	3.58E+01
Arsenic, Inorganic	1.76E+03	4.41E+03	1.68E+01	1.00E+01		2.00E+01	3.07E-01	4.00E+00
Barium	2.71E+02	6.76E+02	4.69E+02	2.00E+03		6.14E+02	6.14E+01	1.23E+02
Beryllium and compounds	5.20E+03	1.30E+04	3.53E-01	4.00E+00		2.36E+01	1.23E-01	4.71E+00
Cadmium	4.94E+02	1.24E+03	4.00E-01	5.00E+00		2.80E+00	1.53E-01	5.61E-01
Calcium	3.39E+01	8.47E+01		NA		NA	NA	NA
Chromium, Total	1.18E+07	2.96E+07	1.15E-03	1.00E+02		Infinite	3.07E+00	2.68E+05
Cobalt	1.05E+03	2.63E+03	6.36E+00	4.70E+00		5.61E+00	1.44E-01	1.12E+00
Copper, Total	4.42E+02	1.10E+03	1.11E+02	1.30E+03		6.51E+02	3.99E+01	1.30E+02
Cyanide (CN-)	6.61E+01	1.65E+02		2.00E+02		1.50E+01	6.14E+00	3.01E+00
Iron	1.45E+03	3.62E+03	8.65E+03	1.10E+04		1.81E+04	3.38E+02	3.61E+03
Lead and compounds	3.29E+04	8.22E+04	3.65E-01	1.50E+01		5.59E+02	4.60E-01	1.12E+02
Magnesium	PARAMETER	PARAMETER	PARAMETER	NA		NA	NA	NA
Manganese	1.76E+03	4.41E+03	1.77E+02	3.20E+02		6.40E+02	9.82E+00	1.28E+02
Mercury (elemental)	3.43E+02	8.57E+02	1.99E-01	2.00E+00		7.78E-01	6.14E-02	1.56E-01
Nickel Soluble Salts	4.29E+02	1.07E+03	2.59E+01	3.00E+02		1.46E+02	9.21E+00	2.92E+01
Potassium	4.94E+02	1.24E+03	NA	NA		NA	NA	NA
Selenium	6.58E+03	1.64E+04	7.30E-01	5.00E+01		3.73E+02	1.53E+00	7.46E+01
Silver	5.93E+02	1.48E+03	3.03E-01	7.10E+01		4.77E+01	2.18E+00	9.55E+00
Sodium, total recoverable	PARAMETER	PARAMETER	PARAMETER	NA		NA	NA	NA
Thallium Soluble Salts	5.27E+02	1.32E+03	6.14E+00	2.00E+00		1.20E+00	6.14E-02	2.39E-01
Uranium (elemental)	1.97E+03	4.93E+03		3.00E+01		6.71E+01	9.21E-01	1.34E+01
Vanadium, total recoverable	6.58E+03	1.64E+04	3.46E+00	7.80E+01		5.82E+02	2.39E+00	1.16E+02
Zinc (metallic)	8.55E+03	2.14E+04	5.67E+00	4.70E+03		4.56E+04	1.44E+02	9.11E+03

Infinite indicates the analyte concentration has exceeded unity, e.g., >1x10E+9 ug/L, >1,000,000mg/kg, >1x10E+12 pCi/g, etc. Blanks indicate result is zero.
PARAMETER indicates that a variable within the equation is not available. 4/23/2012 12:31
NA = Not Available; Red = MCL; Black = USEPA Regional Screening Table http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

Table 8 Tier II Radionuclide Screening Module Results for the Wetlands at Dunbarton Bay

Radioloactive Radiological Analytes	Retardation[27] R (Unitless)	Mean Travel Time[28] T_{Mean} (years)	Groundwater[31] Concentration C_{gw} in Aquifer (pCi/L)	Action Level MCL or PRG (pCi/L)	Analytes Greater Than MCL/PRG/MLSSL and Less Than Evaluation Time (T_e)	Tier II[29] $SSL_{T1/2}$ T1/2-SSL (pCi/g)	Tier II[32] $MLSSL_{T1/2}$ T1/2-MLSSL (pCi/g)	Tier I[26] Default MLSSL (pCi/g)	Tier I[24] Default SSL (pCi/g)
Actinium-228	2.96E+03	7.40E+03		2.66E+01		Infinite	Infinite	2.43E+04	5.30E+05
Americium-241	6.59E+02	1.65E+03		1.50E+01		1.61E+02	5.28E-01	4.72E-01	2.30E+00
Americium-243	6.59E+02	1.65E+03		1.50E+01		1.31E+01	4.64E-01	4.61E-01	2.24E+00
Antimony-124	2.63E+04	6.57E+04		6.00E+01		Infinite	Infinite	2.32E+02	4.51E+04
Antimony-125	2.63E+04	6.57E+04		3.00E+02		Infinite	2.79E+09	6.92E+01	1.34E+04
Carbon-14	3.63E+02	9.06E+02		2.00E+03		9.20E+02	6.20E+01	6.15E+01	1.65E+02
Cesium-134	3.29E+03	8.22E+03		8.00E+01		Infinite	4.18E+11	2.48E+01	6.02E+02
Cesium-137	3.29E+03	8.22E+03		2.00E+02		Infinite	4.23E+01	8.49E+00	2.06E+02
Cobalt-57	6.68E+01	1.67E+02		1.00E+03		Infinite	Infinite	8.60E+02	4.25E+02
Cobalt-60	6.68E+01	1.67E+02		1.00E+02		1.03E+11	1.23E+05	1.23E+01	6.11E+00
Curium-242	2.04E+04	5.10E+04		1.50E+01		Infinite	Infinite	2.14E+01	3.23E+03
Curium-243/244	2.04E+04	5.10E+04		1.50E+01		Infinite	3.56E+00	6.49E-01	9.77E+01
Curium-245/246	2.04E+04	5.10E+04		1.50E+01		2.21E+04	4.64E-01	4.61E-01	6.94E+01
Curium-247	2.04E+04	5.10E+04		1.50E+01		3.47E+02	4.60E-01	4.60E-01	6.93E+01
Europium-152	1.61E+03	4.03E+03		6.00E+01		Infinite	1.27E+02	3.60E+00	4.28E+01
Europium-154	1.61E+03	4.03E+03		2.00E+02		Infinite	3.97E+03	1.60E+01	1.91E+02
Europium-155	1.61E+03	4.03E+03		6.00E+02		Infinite	1.39E+06	7.84E+01	9.34E+02
Iodine-129	2.47E+01	6.17E+01		1.00E+00		2.82E-02	3.07E-02	3.07E-02	5.64E-03
Lead-212	1.78E+03	4.44E+03		2.12E+00		Infinite	Infinite	1.13E+03	1.48E+04
Manganese-54	3.30E+02	8.24E+02		3.00E+02		Infinite	Infinite	2.23E+02	5.44E+02
Neptunium-237	2.31E+02	5.78E+02		1.50E+01		3.94E+00	4.61E-01	4.60E-01	7.87E-01
Neptunium-239	2.31E+02	5.78E+02		3.00E+02		Infinite	Infinite	2.95E+04	5.03E+04
Nickel-59	1.69E+03	4.23E+03		3.00E+02		5.98E+02	9.22E+00	9.21E+00	1.15E+02
Nickel-63	1.69E+03	4.23E+03		5.00E+01		5.57E+14	2.76E+00	1.70E+00	2.12E+01
Niobium-94	3.62E+03	9.04E+03		6.81E+00		3.82E+01	2.10E-01	2.09E-01	5.59E+00
Plutonium-238	3.88E+04	9.70E+04		1.50E+01		Infinite	8.99E-01	5.17E-01	1.48E+02
Plutonium-239/240	3.88E+04	9.70E+04		1.50E+01		1.07E+04	4.62E-01	4.61E-01	1.32E+02
Potassium-40	5.59E+04	1.40E+05	2.59E-01	2.14E+00		1.36E+02	6.57E-02	6.57E-02	2.71E+01
Promethium-147	1.58E+03	3.95E+03		6.00E+02		Infinite	1.61E+10	1.46E+02	1.71E+03
Radium-226	6.59E+02	1.65E+03	1.55E+00	5.00E+00		7.67E+00	1.59E-01	1.54E-01	7.52E-01
Radium-228	6.59E+02	1.65E+03		5.00E+00		Infinite	2.63E+03	5.70E-01	2.78E+00
Sodium-22	6.59E+02	1.65E+03		4.00E+02		Infinite	1.24E+10	9.82E+01	4.78E+02
Strontium-90	5.36E+01	1.34E+02		8.00E+00		1.76E+01	1.88E+00	3.46E-01	1.37E-01
Technetium-99	1.66E+00	4.14E+00		9.00E+02		1.90E+00	2.76E+01	2.76E+01	3.81E-01
Thorium-228	1.32E+04	3.29E+04		1.50E+01		Infinite	5.37E+11	5.01E+00	4.87E+02
Thorium-230	1.32E+04	3.29E+04	1.35E-01	1.50E+01		3.01E+02	4.61E-01	4.61E-01	4.47E+01
Thorium-232	1.32E+04	3.29E+04	1.54E-01	1.50E+01		2.24E+02	4.60E-01	4.60E-01	4.47E+01
Uranium-233/234	1.97E+03	4.93E+03	1.06E+00	1.00E+01		2.27E+01	3.07E-01	3.07E-01	4.48E+00
Uranium-235	1.97E+03	4.93E+03	7.86E-02	5.00E-01		1.12E+00	1.53E-02	1.53E-02	2.24E-01
Uranium-238	1.97E+03	4.93E+03	1.12E+00	1.00E+01		2.24E+01	3.07E-01	3.07E-01	4.48E+00
Zinc-65	4.09E+02	1.02E+03		3.00E+02		Infinite	Infinite	2.87E+02	8.66E+02
Zirconium-95	3.95E+03	9.86E+03		2.00E+02		Infinite	Infinite	7.29E+02	2.13E+04

Infinite indicates the analyte concentration has exceeded unity, e.g., >1x10E+9 ug/L, >1,000,000mg/kg, >1x10E+12 pCi/g, etc. Blanks indicate result is zero.
PARAMETER indicates that a variable within the equation is not available. 4/10/2012 15:40
NA = Not Available; Red = MCL; Black = Savannah River Site Preliminary Remedial Goals

*Uranium isotopic activity in groundwater is calculated for the isotopic distribution of naturally occurring uranium. Total isotopic activity should not exceed 20.5 pCi/L.

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APPENDIX E

RGO Calculations

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The calculations for the remedial goal options (RGOs) for the Wetland Area at Dunbarton Bay are provided in this appendix.

E.1 HUMAN HEALTH RISK-BASED RGOS

The human health risk assessment (HHRA) is presented in Appendix B of this document. HH refined constituents of concern (RCOCs) were identified in ash/soil media for all four of the receptor scenarios that were evaluated in the HHRA, and RGOs are provided for each as appropriate. No HH RCOCs were identified for the surface water media. Human health risk-based RGOs are developed in accordance with the protocol for *Human Health Remedial Goal Options* (WSRC, 2006). Risk-based RGOs are calculated for the future resident, future industrial worker, onsite worker and adolescent trespasser scenarios at various target risk levels (1E-06, 1E-05, and 1E-04). The HH RGOs for ash/soil media at Dunbarton Bay are provided in Table E-1.

E.2 PTSM RGOS

The principal threat source material (PTSM) evaluation is also presented in Appendix B of this document. No PTSM RCOCs were identified for Dunbarton Bay; therefore RGOs are not developed in this appendix.

E.3 ECOLOGICAL RISK-BASED RGOS

The ecological risk assessment (ERA) is presented in Appendix C of this document. No ecological RCOCs were identified for Dunbarton Bay; therefore RGOs are not developed in this appendix.

E.4 CONTAMINANT MIGRATION RGOS

The contaminant migration (CM) analysis and groundwater evaluation is presented in Appendix D of this document. No CM or groundwater RCOCs were identified at Dunbarton Bay; therefore RGOs are not developed in this appendix.

E.5 REFERENCES

WSRC, 2006. *Environmental Restoration Regulatory Document Handbook*, Rev. 16, ERD-AG-003, Washington Savannah River Company

Table E-1. Human Health Risk-Based RGOs

HH RCOC *(units)*	Resident			Industrial Worker			Onsite Worker			Adolescent Trespasser		
	1E-06	1E-05	1E-04	1E-06	1E-05	1E-04	1E-06	1E-05	1E-04	1E-06	1E-05	1E-04
Arsenic *(mg/kg)*	0.39	3.9	39	1.6	16	160	3.32	33.2	332	7.1	71	710
Cesium-137(+D) *(pCi/g)*	0.0623	0.623	6.23	0.103	1.03	10.3	0.204	2.04	20.4	0.272	2.72	27.2
Potassium-40 *(pCi/g)*	0.150	1.50	15.0	0.265	2.65	26.5	0.552	5.52	55.2	0.819	8.19	81.9
Radium-226(+D) *(pCi/g)*	0.0127	0.127	1.27	0.0223	0.223	2.23	0.0464	0.464	4.64	0.0688	0.688	6.88
Uranium-238(+D) *(pCi/g)*	0.725	7.25	72.5	1.49	14.9	149	NA	NA	NA	NA	NA	NA

NA = not applicable; U-238(+D) not identified as a HH RCOC for the Onsite Worker or Adolescent Trespasser scenarios.

APPENDIX F

Cost Estimates

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Abbreviations for Cost Estimates

Abbreviation	Definition
ac	Acre
Is	Item
cy	Cubic Yard
mo	Months
day	Days
lf	Linear Feet
ea	Each
sy	Square Yards

Alternative A-1
No Action
Wetland at Dunbarton Bay
Savannah River Site

Item	Quantity	Units	Unit Cost	Total Cost	
Direct Capital Costs					
No Action					
Subtotal - Direct Capital Cost				$0	*
Mobilization/Demobilization	10%	of subtotal direct capital		$0	*
Site Preparation/Site Restoration	10%	of subtotal direct capital		$0	*
Total Direct Capital Cost		(sum of * items)		**$0**	
Indirect Capital Costs					
Engineering & Design	15%	of direct capital		$0	
Project/Construction Management	25%	of direct capital		$0	
Health & Safety	5%	of direct capital		$0	
Overhead	30%	of direct capital + indirect capital		$0	
Contingency	20%	of direct capital + indirect capital		$0	
Total Indirect Capital Cost				**$0**	
Total Estimated Capital Cost				**$0**	
Direct O&M Costs	2.7%	discount rate for costs > 30 years duration			
Annual Costs (Existing System during Post-ROD Design & Const)	30	year O&M period		*Years 2017 - 2047*	
Subtotal - Annual Costs				$0	
Present Worth Annual Costs				$0	
Five Year Costs	0				
Remedy Review	0	ea	$15,000	$0	
Subtotal - Five Year O&M Costs				$0	
Present Worth Five Year Costs				$0	
Total Present Worth Direct O&M Cost				**$0**	
Indirect O&M Costs					
Project/Admin Management	40%	of direct O&M		$0	
Health & Safety	10%	of direct O&M		$0	
Overhead	30%	of direct O&M + indirect O&M		$0	
Contingency	15%	of direct O&M + indirect O&M		$0	
Total Present Worth Indirect O&M Cost				**$0**	
Total Estimated Present Worth O&M Cost				**$0**	
TOTAL ESTIMATED COST				**$0**	

There are no O&M or 5-year review costs for the No Action alternative, as per EPA-540-R-98-031 guidance.

Alternative A-2
Land Use Controls
Wetland at Dunbarton Bay
Savannah River Site

Item	Quantity	Units	Unit Cost	Total Cost	
Direct Capital Costs					
Institutional Controls					
Posting of Warning Signs	90	ea	$100	$9,000	
Land Use Control Implementation Plan	1	ea	$20,000	$20,000	
Deed Restrictions	1	ea	$5,000	$5,000	
Subtotal - Direct Capital Cost				$34,000	*
Mobilization/Demobilization	25%	of subtotal direct capital		$8,500	*
Site Preparation/Site Restoration	25%	of subtotal direct capital		$8,500	*
Total Direct Capital Cost		(sum of * items)		**$51,000**	
Indirect Capital Costs					
Engineering & Design	14%	of direct capital		$7,140	
Project/Construction Management	25%	of direct capital		$12,750	
Health & Safety	6%	of direct capital		$3,060	
Overhead	30%	of direct capital + indirect capital		$22,185	
Contingency	20%	of direct capital + indirect capital		$19,227	
Total Indirect Capital Cost				**$64,362**	
Total Estimated Capital Cost				**$115,362**	
Direct O&M Costs	0.0%	Discount Rate[1]			
Annual Costs (Existing System during Post-ROD Design & Const)	2	years O&M		*Years 2015 - 2016*	
Access Controls	1	ea	$750	$750	
Subtotal - Annual Costs				$750	
Present Worth Annual Costs (Less than 30-year Duration)				$1,500	
	2.0%	Discount Rate[1]			
Annual Costs (Institutional Controls)	200	years O&M		*Years 2017 - 2217*	
Access Controls	1	ea	$750	$750	
Annual Inspections / Maintenance	1	ea	$5,000	$5,000	
Subtotal - Annual Costs				$5,750	
Present Worth Annual Costs (2.0% Greater Than 30-year Duration)				$282,022	
Periodic Costs: 5-Year Remedy Reviews	40				
Remedy Review	1	ea	$15,000	$15,000	
Subtotal - Five Year O&M Costs				$15,000	
Present Worth Five Year Costs (per EPA 540-R-00-002)				$141,373	
Total Present Worth Direct O&M Cost				**$424,895**	
Indirect O&M Costs					
Project/Admin Management	151%	of direct O&M		$641,592	
Health & Safety	18%	of direct O&M		$76,481	
Overhead	30%	of direct O&M + indirect O&M		$342,890	
Contingency	15%	of direct O&M + indirect O&M		$222,879	
Total Present Worth Indirect O&M Cost				**$1,283,842**	
Total Estimated Present Worth O&M Cost				**$1,708,737**	
TOTAL ESTIMATED COST				**$1,824,099**	

1. Discount Rates from 2012 OMB Circular No. A-94, Appendix C

Alternative A-3a
Excavate Ash/Soil P-Ash Basin to Carolina Bay Buffer (22,000 yd^3), Haul to On-SRS Containment Facility & Land Use Controls
Wetlands at Dunbarton Bay
Savannah River Site

Item	Quantity	Units	Unit Cost	Total Cost	
Direct Capital Costs					
Surveying & Layout					
Topographic Survey - Existing Condition	40	ac	$600	$24,000	
Layout / Survey Support	1	ls	$120,000	$120,000	
Topographic Survey - As Built	40	ac	$600	$24,000	
Access Road					
Temporary Construction Entrance / Access Road	1	ls	$50,000	$50,000	
Clear and Grubbing					
North Section - Clear Heavy Trees, Grub Stumps and Chip	7.3	ac	$6,000	$43,800	
North Section - Load Chipped Material and Haul For Disposal	1100	cy	$16	$17,600	
Middle Section - Clear Light Trees, Grub Stumps and Chip	6.3	ac	$4,500	$28,350	
Middle Section - Load Chipped Material and Haul For Disposal	500	cy	$16	$8,000	
Contour Site After Clearing and Grubbing	13.6	ac	$1,700	$23,120	
Construction Facilities / Temporary Utilities					
Office Trailer / Storage Trailer Rental	12	mo	$1,000	$12,000	
Power, Lighting, Water, Sanitary, Phones, Radios and Vehicles	12	mo	$14,600	$175,200	
Erosion Control					
Silt Fences - Install, Maintain, Remove	12	mo	$2,000	$24,000	
Dewatering	24	day	$3,000	$72,000	
Swales & Diversions - Install and Remove	1540	lf	$4	$6,006	
Dikes - Install and Remove	1000	lf	$5	$4,550	
Check Dams - Install and Remove	15	ea	$2,500	$37,500	
Permanent Check Dams - Install	25	ea	$2,500	$62,500	
Excavate / Load Ash					
North Section	15556	cy	$4	$57,713	
Middle Section	6340	cy	$4	$23,521	
Haul Ash For Disposal On-Site					
North Section (includes 1.2 swell factor)	18667.2	cy	$15	$276,648	
Middle Section (includes 1.2 swell factor)	7608	cy	$15	$112,751	
Dump / Spread / Light Compact Ash At Disposal Site					
North Section	15556	cy	$6	$88,047	
Middle Section	6340	cy	$6	$35,884	
Stormwater Management (Excavation, Structures, Piping and Backfill)	1750	lf	$39	$68,880	
Perimeter Site Restoration (Grading, Fertilizer, Seeding & Watering)	8556	sy	$3	$25,668	
Wetland Restoration	1	ls	$50,000	$50,000	
Institutional Controls					
Posting of Warning Signs	30	ea	$100	$3,000	
Land Use Control Implementation Plan	1	ea	$20,000	$20,000	
Deed Restrictions	1	ea	$5,000	$5,000	
Subtotal - Direct Capital Cost				$1,499,738	*
Mobilization/Demobilization	5%	of subtotal direct capital		$72,737	*
Submittals / Bonds / Subcontract Management	78%	of subtotal direct capital		$1,169,796	*
Total Direct Capital Cost		(sum of * items)		**$2,742,271**	
Indirect Capital Costs					
Engineering & Design	23%	of direct capital		$617,011	
Project/Construction Management	25%	of direct capital		$685,568	
Health & Safety	6%	of direct capital		$164,536	
Overhead	30%	of direct capital + indirect capital		$1,262,816	
Contingency	20%	of direct capital + indirect capital		$1,094,440	
Total Indirect Capital Cost				**$3,824,371**	
Total Estimated Capital Cost				**$6,566,642**	
Direct O&M Costs	0.0%	Discount Rate[1]			
Annual Costs (Existing System during Post-ROD Design & Const)	2	years O&M		*Years 2015 - 2016*	
Access Controls	1	ea	$750	$750	
Subtotal - Annual Costs				$750	
Present Worth Annual Costs (Less Than 30-year Duration)				$1,500	
	2.0%	Discount Rate <30 years duration[1]			
Annual Costs (Institutional Controls)	200	years O&M		*Years 2017 - 2217*	
Access Controls	1	ea	$750	$750	
Annual Inspections / Maintenance	1	ea	$5,000	$5,000	
Subtotal - Annual Costs				$5,750	
Present Worth Annual Costs (Greater than 30-year Duration)				$282,022	
Periodic Costs: 5-Year Remedy Reviews	40				
Remedy Review	1	ea	$15,000	$15,000	
Subtotal - Five Year O&M Costs				$15,000	
Present Worth Five Year Costs (per EPA 540-R-00-002)				$141,373	
Total Present Worth Direct O&M Cost				**$424,895**	
Indirect O&M Costs					
Project/Admin Management	151%	of direct O&M		$641,591	
Health & Safety	18%	of direct O&M		$76,481	
Overhead	30%	of direct O&M + indirect O&M		$342,890	
Contingency	15%	of direct O&M + indirect O&M		$222,879	
Total Present Worth Indirect O&M Cost				**$1,283,841**	
Total Estimated Present Worth O&M Cost				**$1,708,736**	
TOTAL ESTIMATED COST				**$8,275,378**	

1. Discount Rates from 2012 OMB Circular No. A-94, Appendix C

Alternative A-3b
Excavate Ash/Soil P-Ash Basin to Carolina Bay Buffer (22,000 yd^3), Haul to Off-SRS Containment Facility & Land Use Controls
Wetlands at Dunbarton Bay
Savannah River Site

Item	Quantity	Units	Unit Cost	Total Cost
Direct Capital Costs				
Surveying & Layout				
Topographic Survey - Existing Condition	40	ac	$600	$24,000
Layout / Survey Support	1	ls	$120,000	$120,000
Topographic Survey - As Built	40	ac	$600	$24,000
Access Road				
Temporary Construction Entrance / Access Road	1	ls	$50,000	$50,000
Clear and Grubbing				
North Section - Clear Heavy Trees, Grub Stumps and Chip	7.3	ac	$6,000	$43,800
North Section - Load Chipped Material and Haul For Disposal	1100	cy	$16	$17,600
Middle Section - Clear Light Trees, Grub Stumps and Chip	6.3	ac	$4,500	$28,350
Middle Section - Load Chipped Material and Haul For Disposal	500	cy	$16	$8,000
Contour Site After Clearing and Grubbing	13.6	ac	$1,700	$23,120
Construction Facilities / Temporary Utilities				
Office Trailer / Storage Trailer Rental	12	mo	$1,000	$12,000
Power, Lighting, Water, Sanitary, Phones, Radios and Vehicles	12	mo	$14,600	$175,200
Erosion Control				
Silt Fences - Install, Maintain, Remove	12	mo	$2,000	$24,000
Dewatering	24	day	$3,000	$72,000
Swales & Diversions - Install and Remove	1540	lf	$4	$6,006
Dikes - Install and Remove	1000	lf	$5	$4,550
Check Dams - Install and Remove	15	ea	$2,500	$37,500
Permanent Check Dams - Install	25	ea	$2,500	$62,500
Excavate / Load Ash				
North Section	15556	cy	$4	$57,713
Middle Section	6340	cy	$4	$23,521
Haul Ash For Disposal Off-Site (Three Rivers Landfill)				
North Section (includes 1.2 swell factor)	18667.2	cy	$16	$298,675
Middle Section (includes 1.2 swell factor)	7608	cy	$16	$121,728
Three Rivers Landfill Disposal Fee	43736	ton	$45	$1,968,120
Dump / Spread / Light Compact Ash At Disposal Site				
North Section	15556	cy	$6	$88,047
Middle Section	6340	cy	$6	$35,884
Stormwater Management (Excavation, Structures, Piping and Backfill)	1750	lf	$39	$68,880
Perimeter Site Restoration (Grading, Fertilizer, Seeding & Watering)	8556	sy	$3	$25,668
Wetland Restoration	1	ls	$50,000	$50,000
Institutional Controls				
Posting of Warning Signs	30	ea	$100	$3,000
Land Use Control Implementation Plan	1	ea	$20,000	$20,000
Deed Restrictions	1	ea	$5,000	$5,000
Subtotal - Direct Capital Cost				$3,498,863 *
Mobilization/Demobilization	2%	of subtotal direct capital		$78,724 *
Submittals / Bonds / Subcontract Management	37%	of subtotal direct capital		$1,294,579 *
Total Direct Capital Cost		(sum of * items)		**$4,872,166**
Indirect Capital Costs				
Engineering & Design	14%	of direct capital		$682,103
Project/Construction Management	15%	of direct capital		$730,825
Health & Safety	4%	of direct capital		$175,398
Overhead	30%	of direct capital + indirect capital		$1,938,148
Contingency	17%	of direct capital + indirect capital		$1,427,769
Total Indirect Capital Cost				**$4,954,243**
Total Estimated Capital Cost				**$9,826,409**
Direct O&M Costs	0.0%	Discount Rate[1]		
Annual Costs (Existing System during Post-ROD Design & Const)	2	years O&M		*Years 2015 - 2016*
Access Controls	1	ea	$750	$750
Subtotal - Annual Costs				$750
Present Worth Annual Costs (Less Than 30-year duration)				$1,500
	2.0%	Discount Rate[1]		
Annual Costs (Institutional Controls)	200	years O&M		*Years 2017 - 2217*
Access Controls	1	ea	$750	$750
Annual Inspections / Maintenance	1	ea	$5,000	$5,000
Subtotal - Annual Costs				$5,750
Present Worth Annual Costs (Greater Than 30-year duration)				$282,022
Periodic Costs: 5-Year Remedy Review	40			
Remedy Review	1	ea	$15,000	$15,000
Subtotal - Five Year O&M Costs				$15,000
Present Worth Five Year Costs (per EPA 540-R-00-002)				$141,373
Total Present Worth Direct O&M Cost				**$424,895**
Indirect O&M Costs				
Project/Admin Management	151%	of direct O&M		$641,591
Health & Safety	18%	of direct O&M		$76,481
Overhead	30%	of direct O&M + indirect O&M		$342,890
Contingency	15%	of direct O&M + indirect O&M		$222,879
Total Present Worth Indirect O&M Cost				**$1,283,841**
Total Estimated Present Worth O&M Cost				**$1,708,736**
TOTAL ESTIMATED COST				**$11,535,146**

1 Discount Rates from 2012 OMB Circular No. A-94, Appendix C

Alternative A-3c
Excavation (20,000 yd³) and Haul To On-Site Disposal Area
Dunbarton Bay OU Ash
Savannah River Site

Item	Quantity	Units	Unit Cost	Total Cost	
Direct Capital Costs					
Surveying & Layout					
Topographic Survey - Existing Condition	40	ac	$600	$24,000	
Layout / Survey Support	1	ls	$120,000	$120,000	
Topographic Survey - As Built	40	ac	$600	$24,000	
Access Road					
Temporary Construction Entrance / Access Road	1	ls	$50,000	$50,000	
Clear and Grubbing					
North Section - Clear Heavy Trees, Grub Stumps and Chip	7.3	ac	$6,000	$43,800	
North Section - Load Chipped Material and Haul For Disposal	1100	cy	$16	$17,600	
Middle Section - Clear Light Trees, Grub Stumps and Chip	6.3	ac	$4,500	$28,350	
Middle Section - Load Chipped Material and Haul For Disposal	500	cy	$16	$8,000	
Carolina Bay Section - Clear Heavy Trees, Grub Stumps and Chip	23.6	ac	$6,000	$141,600	
Carolina Bay Section - Load Chipped Material and Haul For Disposal	3540	cy	$16	$56,640	
Contour Site After Clearing and Grubbing	37.2	ac	$1,700	$63,240	
Construction Facilities / Temporary Utilities					
Office Trailer / Storage Trailer Rental	18	mo	$1,000	$18,000	
Power, Lighting, Water, Sanitary, Phones, Radios and Vehicles	18	mo	$14,600	$262,800	
Erosion Control					
Silt Fences - Install, Maintain, Remove	18	mo	$2,000	$36,000	
Dewatering	48	day	$3,000	$144,000	
Swales & Diversions - Install and Remove	3080	lf	$4	$12,012	
Dikes - Install and Remove	2000	lf	$5	$9,100	
Check Dams - Install and Remove	30	ea	$2,500	$75,000	
Permanent Check Dams - Install	50	ea	$2,500	$125,000	
Excavate / Load Ash					
North Section	15556	cy	$4	$57,713	
Middle Section	14815	cy	$4	$54,964	
Carolina Bay Section	49926	cy	$4	$185,225	
Haul Ash For Disposal On-Site					
North Section (includes 1.2 swell factor)	18668	cy	$15	$276,660	
Middle Section (includes 1.2 swell factor)	17778	cy	$15	$263,470	
Carolina Bay Section (includes 1.2 swell factor)	59912	cy	$15	$887,896	
Dump / Spread / Light Compact Ash At Disposal Site					
North Section	15556	cy	$6	$88,047	
Middle Section	14815	cy	$6	$83,853	
Carolina Bay Section	49926	cy	$6	$282,581	
Stormwater Management (Excavation, Structures, Piping and Backfill)	3500	lf	$39	$137,760	
Perimeter Site Restoration (Grading, Fertilizer, Seeding & Watering)	28288	sy	$3	$84,864	
Wetland Restoration	1	ls	$100,000	$100,000	
Subtotal - Direct Capital Cost				$3,762,174	*
Mobilization/Demobilization	2%	of subtotal direct capital		$84,649	*
Submittals / Bonds / Subcontract Management	50%	of subtotal direct capital		$1,881,087	*
Total Direct Capital Cost		(sum of * items)		**$5,727,911**	
Indirect Capital Costs					
Engineering & Design	14%	of direct capital		$801,907	
Project/Construction Management	25%	of direct capital		$1,431,978	
Health & Safety	6%	of direct capital		$343,675	
Overhead	30%	of direct capital + indirect capital		$2,491,641	
Contingency	20%	of direct capital + indirect capital		$2,159,422	
Total Indirect Capital Cost				**$7,228,623**	
Total Estimated Capital Cost				**$12,956,534**	
Direct O&M Costs	0.0%	Discount Rate[1]			
Annual Costs (Existing System during Post-ROD Design & Const)	2	years O&M		*Years 2015 - 2016*	
Access Controls	1	ea	$750	$750	
Subtotal - Annual Costs				$750	
Present Worth Annual Costs (Less Than 30-year Duration)				$1,500	
Total Present Worth Direct O&M Cost				**$1,500**	
Indirect O&M Costs					
Project/Admin Management	2150%	of direct O&M		$32,250	
Health & Safety	2150%	of direct O&M		$32,250	
Overhead	30%	of direct O&M + indirect O&M		$19,800	
Contingency	15%	of direct O&M + indirect O&M		$12,870	
Total Present Worth Indirect O&M Cost				**$97,170**	
Total Estimated Present Worth O&M Cost				**$98,670**	
TOTAL ESTIMATED COST				**$13,055,204**	

1. Discount Rates from 2012 OMB Circular No. A-94, Appendix C

Alternative A-3d
Excavation (80,200 yd^3) and Haul To Off-Site Disposal Area
Dunbarton Bay OU Ash
Savannah River Site

Item	Quantity	Units	Unit Cost	Total Cost
Direct Capital Costs				
Surveying & Layout				
Topographic Survey - Existing Condition	40	ac	$600	$24,000
Layout / Survey Support	1	ls	$120,000	$120,000
Topographic Survey - As Built	40	ac	$600	$24,000
Access Road				
Temporary Construction Entrance / Access Road	1	ls	$50,000	$50,000
Clear and Grubbing				
North Section - Clear Heavy Trees, Grub Stumps and Chip	7.3	ac	$6,000	$43,800
North Section - Load Chipped Material and Haul For Disposal	1100	cy	$16	$17,600
Middle Section - Clear Light Trees, Grub Stumps and Chip	6.3	ac	$4,500	$28,350
Middle Section - Load Chipped Material and Haul For Disposal	500	cy	$16	$8,000
Carolina Bay Section - Clear Heavy Trees, Grub Stumps and Chip	23.6	ac	$6,000	$141,600
Carolina Bay Section - Load Chipped Material and Haul For Disposal	3540	cy	$16	$56,640
Contour Site After Clearing and Grubbing	37.2	ac	$1,700	$63,240
Construction Facilities / Temporary Utilities				
Office Trailer / Storage Trailer Rental	18	mo	$1,000	$18,000
Power, Lighting, Water, Sanitary, Phones, Radios and Vehicles	18	mo	$14,600	$262,800
Erosion Control				
Silt Fences - Install, Maintain, Remove	18	mo	$2,000	$36,000
Dewatering	48	day	$3,000	$144,000
Swales & Diversions - Install and Remove	3080	lf	$4	$12,012
Dikes - Install and Remove	2000	lf	$5	$9,100
Check Dams - Install and Remove	30	ea	$2,500	$75,000
Permanent Check Dams - Install	50	ea	$2,500	$125,000
Excavate / Load Ash				
North Section	15556	cy	$4	$57,713
Middle Section	14815	cy	$4	$54,964
Carolina Bay Section	49926	cy	$4	$185,225
Haul Ash For Disposal Off-Site (Three Rivers Landfill)				
North Section (includes 1.2 swell factor)	18668	cy	$16	$298,688
Middle Section (includes 1.2 swell factor)	17778	cy	$16	$284,448
Carolina Bay Section (includes 1.2 swell factor)	59912	cy	$16	$958,592
Three Rivers Landfill Disposal Fee	115630	ton	$45	$5,203,350
Dump / Spread / Light Compact Ash At Disposal Site				
North Section	15556	cy	$6	$88,047
Middle Section	14815	cy	$6	$83,853
Carolina Bay Section	49926	cy	$6	$282,581
Stormwater Management (Excavation, Structures, Piping and Backfill)	3500	lf	$39	$137,760
Perimeter Site Restoration (Grading, Fertilizer, Seeding & Watering)	28288	sy	$3	$84,864
Wetland Restoration	1	ls	$100,000	$100,000
Subtotal - Direct Capital Cost				$9,079,227 *
Mobilization/Demobilization	1%	of subtotal direct capital		$85,345 *
Submittals / Bonds / Subcontract Management	21%	of subtotal direct capital		$1,906,638 *
Total Direct Capital Cost		(sum of * items)		**$11,071,209**
Indirect Capital Costs				
Engineering & Design	8%	of direct capital		$830,341
Project/Construction Management	13%	of direct capital		$1,439,257
Health & Safety	3%	of direct capital		$332,136
Overhead	30%	of direct capital + indirect capital		$4,101,883
Contingency	20%	of direct capital + indirect capital		$3,554,965
Total Indirect Capital Cost				**$10,258,583**
Total Estimated Capital Cost				**$21,329,792**
Direct O&M Costs	0.0%	Discount Rate[1]		
Annual Costs (Existing System during Post-ROD Design & Const)	2	years O&M		*Years 2015 - 2016*
Access Controls	1	ea	$750	$750
Subtotal - Annual Costs				$750
Present Worth Annual Costs (Less Than 30-year Duration)				$1,500
Total Present Worth Direct O&M Cost				**$1,500**
Indirect O&M Costs				
Project/Admin Management	2150%	of direct O&M		$32,250
Health & Safety	2150%	of direct O&M		$32,250
Overhead	30%	of direct O&M + indirect O&M		$19,800
Contingency	15%	of direct O&M + indirect O&M		$12,870
Total Present Worth Indirect O&M Cost				**$97,170**
Total Estimated Present Worth O&M Cost				**$98,670**
TOTAL ESTIMATED COST				**$21,428,462**

1. Discount Rates from 2012 OMB Circular No. A-94, Appendix C

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APPENDIX G

Natural Resource Injury Evaluation

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Natural Resource Injury Evaluation

This section discusses suspected or known natural resource injuries. The potential for injuries is documented by completing the Natural Resource Injury Evaluation (NRIE) Checklist. The purpose of the NRIE checklist is to identify potential natural resource injuries associated with CERCLA remedial activities. If potential injuries are identified, consideration is given as to whether or not trustee involvement is needed. The checklist is a starting point in potential injury identification and is not intended to be all-inclusive. The checklist has been designed as a series of questions to help identify the potential for natural resource injuries and what resources may be affected. It is based on the pre-assessment screen in Title 43 *Code of Federal Regulations* Part 11.13.

NRIEs are based on the SRS Natural Resource Trustee Responsibilities List of Trust Resources (Table G-1). If natural resources at the site under trusteeship have been, or are likely to be, adversely affected by the released substance or associated remediation, and if the quantity and concentration of the released substance are sufficient to potentially cause injury to natural resources, then consideration should be given as to whether trustee involvement is warranted. If potential injuries are found, consideration should be given as to whether trustee involvement is needed. The Natural Resource Trustees review this information to determine if their trustee resources may be injured and determine the level of involvement that is warranted.

The plan is to prevent potential injuries to natural resources that can occur as the result of remediation activities and to mitigate, to the extent practical, any injuries that have already occurred. Trustees are consulted early in the scoping process so they can provide effective input for decisions regarding natural resources.

RCOCs have been identified in the Wetland Area at Dunbarton Bay. Based on the NRIE Checklist (Table G-2), natural resources in the locale have been impacted by hazardous substances from the unit. Remedial alternatives under consideration may or may not address injuries to the natural resources. Remedial alternatives considered may cause additional injury based on the scope of the action (e.g., excavation within the Carolina Bay). No irreversible or irretrievable resource losses are known to exist.

Table G-1. Savannah River Site Natural Resource Trustees and Their Responsibilities

Governing Power	Responsibilities
U.S. Department of Energy, Savannah River Operations Office	All natural resources located on, over, or under land administered by USDOE
South Carolina Office of the Governor	All natural resources of the State of South Carolina
South Carolina Department of Health and Environmental Control, Bureau of Land and Waste Management	Geologic resources including soil, groundwater resources (including drinking water sources), air resources, and surface water resources
U.S. Department of the Interior	Threatened and endangered species (includes Red-Cockaded Woodpecker, Bald Eagle, Wood Stork, Shortnose Sturgeon, and Smooth Coneflower), migratory birds, anadromous species, National Park Service land (Fort Pulaski National Monument), Fish and Wildlife Service land (Savannah River National Wildlife Refuge), Tybee Island National Wildlife Refuge, and Orangeburg National Fish Hatchery
South Carolina Department of Natural Resources	Commercial species, game and non-game species, and state sensitive species
Georgia Department of Natural Resources	Savannah River resources, groundwater resources, air resources, and surface water resources
U.S. Department of Commerce, National Oceanic and Atmospheric Administration	Living and non-living natural resources in coastal and marine areas including the following: • All life stages, wherever they occur, of fishery resources on the Exclusive Economic Zone and continental shelf • Anadromous and catadromous species throughout their ranges, rivers, and tributaries to rivers, which historically or presently support the above species • Federally endangered and threatened species, including designated critical habitat and marine mammals for which NOAA has assigned responsibility • Tidal wetlands, salt marshes, estuaries, and all other habitats supporting all fishery and marine resources listed above • Living and non-living resources of National Marine Sanctuaries and National Estuarine Reserves
U.S. Army Corps of Engineers, Charleston, South Carolina District, Savannah, Georgia District	Savannah River resources, navigable waters resources, and waters of the United States resources

Table G-2. Natural Resource Injury Evaluation Checklist

This checklist is provided to assist project teams in determining the potential for natural resource injuries in the conduct and planning of remedial activities. For the most part, the questions only require a simple 'yes/no' or 'to be determined' response. Some require a short answer or explanation. However, it is in the best interest of the project team to be as complete as possible and add any relevant information.
Five main areas are being evaluated, as follows:

- Are there potential natural resource injuries and what do they consist of?
- What are the potential impacts from implementing the remedial alternatives?
- Are there potential residual injuries that will not be addressed by the alternative?
- Would implementation of the alternative cause additional injuries?
- What potential irreversible and irretrievable resources may be identified?

The checklist should be re-visited and revised as CERCLA/RCRA activities continue and additional information becomes available.

1. Has a release of a hazardous substance occurred?
   Yes. Unit-related constituents were identified in soil/sediment media.

2a. Have natural resources for which Federal or State agencies (or Indian Tribes) may assert trusteeship under CERCLA been or are likely to have been adversely affected by the release?
Yes.

Natural resources are defined by Section 101(16) of CERCLA, as "land, fish, wildlife, biota, air, water, groundwater, drinking water supplies, and other such resources". The NCP Section 300.600(b) indicates that natural resources may include not only the environmental organisms and abiotic resources, but the "supporting ecosystems associated with the biotic resources" as well. Resources are categorized into five groups: Surface water resources, groundwater resources, air resources, geologic resources, and biological resources. Resources can also be classified as direct use (such as drinking water, hunting, etc.) or nonuse (such as aesthetic value or existence). Nonuse services do not require physical or visual contact between people and the resource. Nonuse resources include resources that provide well-being for people (or other flora/fauna) because they exist. For example, nesting sites, threatened and endangered species, natural areas, etc.

2b. List the potentially affected resources (e.g. ground water, waterfowl, etc.).
Potentially affected resources include geologic resources (soil/sediment). The human health risk evaluation indicates that the abiotic media contain constituents of concern.

3. Is the amount of hazardous substance released sufficient to potentially cause a natural resource injury?
   Yes.

4. Will the remedial alternatives being considered, or action already taken, sufficiently address the injuries to natural resources (including residual injuries)?
   Remedial alternatives are identified and evaluated in the CMS/FS. Each alternative is evaluated as to whether it would be protective of human health and the environment.

5. Will the remedial alternatives being considered produce additional impacts to natural resources during remediation? If yes, the potential impacts associated with each alternative need to be identified and discussed in the appropriate documentation including the feasibility study, statement of basis/proposed plan, record of decision or permit modification.
   Remedial alternatives are identified and evaluated in the CMS/FS. Each alternative is evaluated as to whether it would be protective of human health and the environment.

   The potential costs for addressing resource injuries should be taken into consideration when selecting a remedial alternative. The liability (damage) associated with resource injuries could drive the cost of the intended best or lowest cost alternative.

6. Identify any irreversible and/or irretrievable resource losses in the appropriate documentation.
   No irreversible and/or irretrievable resource losses are known to exist.

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