REMEDIAL INVESTIGATION REPORT

Indian River Generating Station
Operable Unit No. 2
Burton Island Historical Ash Disposal Area
Millsboro, Delaware

Site Number DE-1399

Prepared for:

Indian River Power, LLC (an NRG Energy Company)
Power Plant Road
P.O. Box 408
Millsboro, DE 19966

Prepared by:

Shaw Environmental, Inc.

200 Horizon Center Boulevard
Trenton, NJ 08691

Shaw Project No. 1009684028

February 2011

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List of Acronyms

AFB	Air Force Base
ASOS	Automated Surface Observing System
ASTM	American Society for Testing and Materials
AUFs	area use factors
AWA	Assawoman Wildlife Area
BAF	bioaccumulation factor
BCF	bioconcentration factor
bgs	below ground surface
BSV	background screening value
BTF	biotransfer factor
CDI	chronic daily intake
COIs	Constituents of Interest
COPCs	Constituents of Potential Concern
COPECs	Constituents of Potential Environmental Concern
CSM	Conceptual Site Model
DD	daily dose
DNREC	Delaware Department of Natural Resources and Environmental Control
E2EM	Estuarine Intertidal Emergent
E2FO	Estuarine Intertidal Forested
E2SS	Estuarine Intertidal Scrub/Shrub
EDD	electronic data deliverable
EFH	Essential Fish Habitat
EHQ	ecological hazard quotient
EPC	exposure point concentration
ESV	ecological screening value
FCM	food chain multiplier
FE	Facility Evaluation
ft	foot/feet
GCMS	gas chromatography/mass spectrometry
g/L	grams per Liter
GPS	global positioning system
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HI	hazard index

List of Acronyms (continued)

HQ	hazard quotient
IRIS	Integrated Risk Information System
LOAEL	lowest-observed-adverse-effect-level
MW	megawatt
mg/L	milligrams per Liter
mg/kg	milligram per kilogram
µg/L	micrograms per Liter
µR/hr	microR per hour
µS/cm	micro-Siemens per centimeter
m/s	meters per second
mS/cm	milli-Siemens per centimeter
msl	mean sea level
mV	millivolts
NAAQS	National Ambient Air Quality Standards
NCA	National Coastal Assessment
NED	National Elevation Dataset
NMFS	National Marine Fisheries Service
NOAEL	no-observed-adverse-effect-level
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRG	NRG Energy
NTU	Nephelometric Turbidity Units
ORP	Oxidation-Reduction Potential
OU	Operable Unit
PCBs	polychlorinated biphenyls
PM	particulate matter
ppt	parts per thousand
PVC	polyvinyl chloride
RfC	reference concentration
RfD	reference dose
RI	Remedial Investigation
RIWP	Remedial Investigation Work Plan
RME	reasonable maximum exposure
RUSLE	Revised Universal Soil Loss Equation

List of Acronyms (continued)

SC	specific conductance
SF	slope factor
Shaw	Shaw Environmental, Inc.
SIRB	Site Investigation and Restoration Branch
SLERA	Screening Level Ecological Risk Assessment
SVOCs	semi-volatile organic compounds
TAL	Target Analyte List
TDS	total dissolved solids
TOC	Total Organic Carbon
TRV	toxicity reference values
TSP	Total Suspended Particulates
UCL	upper confidence limit
UF	uncertainty factor
URS	Uniform Risk-Based Remediation Standards
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTL	upper tolerance level
VCP	Voluntary Cleanup Program
VOCs	volatile organic compounds
WLE	water level elevation
WRS	Wilcoxon Rank Sum

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Section 2.2 - Geologic Conditions, Section 2.3 - Hydrogeologic Conditions, and Section 3.3 - Groundwater of this submission are made in compliance with 24 Del.C., Ch. 36 by Richard T. Wardrop, P. G., DE License Number 392 on this date, February 28, 2011.

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Executive Summary

Shaw Environmental, Inc. (Shaw) prepared this remedial investigation (RI) report on behalf of Indian River Power LLC, for the Burton Island Historical Ash Disposal Area (hereinafter referred to as 'the Site') located east of the Indian River Generating Station. This RI follows the Facility Evaluation (FE) and was performed in conjunction with the Scope of Work outlined in the Voluntary Cleanup Program (VCP) Agreement DE-1399 between the Delaware Department of Natural Resources and Environmental Control (DNREC) and Indian River Power LLC, a wholly owned subsidiary of NRG Energy, Inc. (NRG). The FE was completed in 2008.

The areas of investigation for the Site are addressed as three Operable Units (OUs). The OUs are designated in the VCP Agreement generally as OU1 – shoreline, OU2 – former disposal areas inside shoreline, and OU3 – offshore.

The FE report discussed the nature and extent of the constituents of interest (COIs) for the three OUs, as well as their fate and transport based on site data collected in 2007. The FE report also contained both a Human Health Risk Assessment (HHRA) and a Screening Level Ecological Risk Assessment (SLERA). On July 30, 2008, DNREC issued an *Approval of Final Plan of Remedial Action for Burton Island Ash Disposal Area (Operable Units 1 & 3)* (DNREC, 2008). DNREC approved of the results of the FE for OU1 and OU3, reflecting that there were no significant human health risks from these OUs, and identified that additional investigation was warranted for OU2. Specifically, DNREC identified several data gaps in the assessments conducted for OU2 in the FE as follows:

1. The HHRA did not assess potential exposures to ash material at OU2.
2. The HHRA did not assess the potential exposures of off-site receptors being exposed to impacted groundwater or inhalation of wind-generated fugitive dust.
3. The terrestrial food web models in the SLERA lacked site-specific information that could be useful in refining the potential terrestrial food web interactions that were assessed in the SLERA.
4. The HHRA and the SLERA lacked surface soil data to characterize exposures.

This RI was conducted in order to refine assumptions and fill data gaps for the OU2 risk assessment. This RI characterized the environmental media (e.g. surface and subsurface landfill material, groundwater, pond surface water, and pond sediment), and the potential human health and ecological risks at OU2.

Environmental Conditions

The existing environmental conditions including physiographic, geologic, and hydrogeologic conditions, as well as the surface features including wildlife, vegetative and habitat communities, wetlands, and surface water, were determined using available local data and specific field efforts. Specifically for this RI, a vegetative cover and habitat survey in OU2 and a characterization of the three ponds were conducted. OU2 is densely vegetated, with limited areas of exposed ash (approximately one acre total) and three surface water ponds. Other than the three ponds, no wetlands were identified in the interior of OU2. The ponds have direct connection to surrounding tidal surface waters during certain high tides.

RI Activities and Supporting Data

OU2 has been defined through previous investigations. Supplemental investigations completed for this RI included the collection of 14 surface (0-6" depth) and 14 subsurface (2'-3' depth) composite landfill material samples, soil samples from drilling cores, 3 surface water and 3 sediment samples in ponds, and groundwater samples from 14 monitoring wells. The RI activities also included a tidal gauging study. These data are used in support of the revised risk assessment.

Surface and Subsurface Landfill Material

The landfill materials sampled during the surface and subsurface field investigation were predominantly very fine grained, gray, loose ash with sand cover. Current facility knowledge and the field investigation indicate that the coal used at the facility while the Site was in operation was always eastern bituminous. Statistical analyses of the analytical results for Target Analyte List (TAL) metals support the conclusion that detected metal concentrations in surface and subsurface materials are not statistically different and that these materials are generally homogeneous.

Pond Surface Water and Sediment

The investigation of the ponds confirmed that the condition of the surface water and sediment in these ponds is consistent with the condition of the surface water and sediment in the adjacent Indian River and Island Creek. Thus, the following conclusions of the FE with regard to surface water and sediment are applicable to the three ponds investigated as part of this RI.

For sediment:

1) no ecological hazard from exposure to sediment through food web interactions;
2) possible but not probable potential for adverse effects on benthic invertebrates due to arsenic and barium in sediment; and
3) no further ecological evaluation is recommended for sediment.

For surface water:

1) no ecological hazard from exposure to surface water through food web interactions;
2) the likelihood of adverse effects from exposure to arsenic and barium in surface water is minimal; and
3) no further ecological evaluation is recommended for surface water.

Groundwater

A groundwater investigation was conducted to assess the water-bearing zones in the region around Burton Island and the connectivity between groundwater under OU2 and both the surface water and local drinking water aquifer. The groundwater investigation included a desktop information search, monitoring well installation, groundwater sampling, and a tidal study. The result is a revised conceptual site model and mass loading analysis. The data indicates that groundwater at Burton Island does not connect to the local drinking water aquifer and instead discharges intermittently with the tides to surface water at low tides.

Overland Flow Pathway

An evaluation of the mass loading for arsenic to Island Creek and Indian River from Burton Island via the overland flow pathway (stormwater runoff) confirms that the contribution of landfill material to the surrounding surface waters has been significantly reduced by the shoreline stabilization project. As such, the condition of no significant risk from exposure to surface water and sediment as described in the FE and supported with empirical data is not anticipated to change due to potential overland flow contribution.

Air Dispersion Modeling

Atmospheric dispersion modeling was performed as a means of estimating ambient particulate matter (PM) concentrations in the local area due to potential wind erosion from OU2. The results of both the conservative screening modeling analysis and the more refined modeling indicate that the National Ambient Air Quality Standards (NAAQS) are not exceeded under current conditions at OU2.

Human Health Risk Assessment

A HHRA was conducted to determine the types and magnitudes of exposures to constituents originating from OU2 and to determine the potential carcinogenic risks and non-carcinogenic health hazards posed by the estimated exposures.

The only constituent that was identified as a constituent of potential concern (COPC) in surface soil at OU2 was arsenic. Based on current and expected future uses of the Site, recreational fishermen and their families is the only population potentially exposed to COPCs at OU2. This population could potentially be exposed to COPCs via ingestion of fish/shellfish, combined with the incidental ingestion of soil and dermal absorption of soil while trespassing on Burton Island.

The HHRA indicates that site-related constituents in surface soil and sediment generally do not pose significant risks/hazards to recreational fishermen or their families, though there is limited risk associated with arsenic exposure, which has the potential for increased carcinogenic risk and non-carcinogenic hazard assuming conservative exposure parameters, under unlikely circumstances (trespassing illegally upon the site more than 15 times per year). Further, it should be noted that the DNREC Division of Water Resources currently prohibits the harvesting of shellfish from the waters of the Delaware Inland Bays for reasons not associated with the facility or its operations. If more realistic exposure parameters are considered compared to the conservative exposure parameters currently assumed in the HHRA, the estimated carcinogenic risks and non-carcinogenic hazards associated with exposure to surface material at OU2 are less than the recommended risk/hazard levels specified by the U.S. Environmental Protection Agency (USEPA) and DNREC.

Screening Level Ecological Risk Assessment

A SLERA was presented in the FE that assessed OU1, OU2, and OU3 and consisted of an evaluation of sensitive habitats, receptors, and exposure pathways at or in the vicinity of the Site. The SLERA was revised in this RI for OU2 to consider updated site-specific information with respect to the environmental setting, the identification of constituents of potential ecological concern (COPECs), identification of receptors and exposure pathways, analysis of potential effects, and ultimately characterization of potential risks.

Ecological hazards were estimated for both community-level ecological receptors and higher trophic level receptors at OU2. Conservative assessment techniques were utilized for all exposures and assessment endpoints. Surface soil samples collected from OU2 exhibit concentrations of several metals (arsenic, barium, mercury, selenium, and thallium) that may have the potential to affect the site's ecosystem.

Uncertainties are inherent in any risk assessment, and even more so in a SLERA due to the conservative nature of the assessment process and the assumptions used in the process. In general, uncertainties in risk assessments are mitigated by making conservative assumptions so that risks are not under-estimated, resulting in a conservative risk assessment. The results of the terrestrial food web model showed that the calculated ecological hazard quotients (EHQs) for several of the feeding guilds were greater than one, indicating the potential for ecological hazard due to exposures to COPECs in surface soil at OU2. However, if food web models were utilized to assess ecological communities and populations instead of individuals, then the calculated hazards would be less than the *de minimus* hazard levels and no food web impacts to terrestrial populations would be expected.

1.0 Introduction

Shaw Environmental, Inc. (Shaw) prepared this remedial investigation (RI) report on behalf of Indian River Power, LLC, for the Burton Island Historical Ash Disposal Area (hereinafter referred to as 'Ash Site') located east of the Indian River Generating Station. This RI is the second work scope that was implemented in conjunction with the Scope of Work outlined in the Voluntary Cleanup Program (VCP) Agreement DE-1399 between the Delaware Department of Natural Resources and Environmental Control (DNREC) and Indian River Power, LLC, a wholly owned subsidiary of NRG Energy (NRG).

The Operable Units (OUs) are designated in the VCP Agreement as follows:

- **OU1**: the shoreline areas of the Ash Site including any areas that would be encompassed within the area of the erosion control project.
- **OU2**: the area of the Ash Site inside (landward) of OU1 including the disposal areas.
- **OU3**: any subaqueous lands, wetlands, waters, or lands outside (riverward) of OU1 to which wastes or contaminants may have been conveyed (but excluding the currently operating permitted landfill and any legal off-site disposal).

DNREC issued the *Final Plan of Remedial Action, Burton Island Old Ash Landfill Site, Operable Units 1 and 3* on August 5, 2008 based on the findings of the Facility Evaluation (FE; Shaw, 2008). This RI of OU2 at the Ash Site was conducted in order to provide information for the following purposes:

- Refine assumptions regarding OU2 that were used in the FE (Shaw, 2008);
- Fill data gaps; and
- Provide sufficient information to make informed management decisions regarding OU2 under the VCP.

The RI of OU2 characterized the environmental media (e.g. surface and subsurface soil, groundwater, pond surface water, and pond sediment), and the potential human health and ecological risks at OU2. Thus, the RI for OU2 is a revision of and supplement to the data and analysis presented in the FE for OU2.

1.1 Facility Description

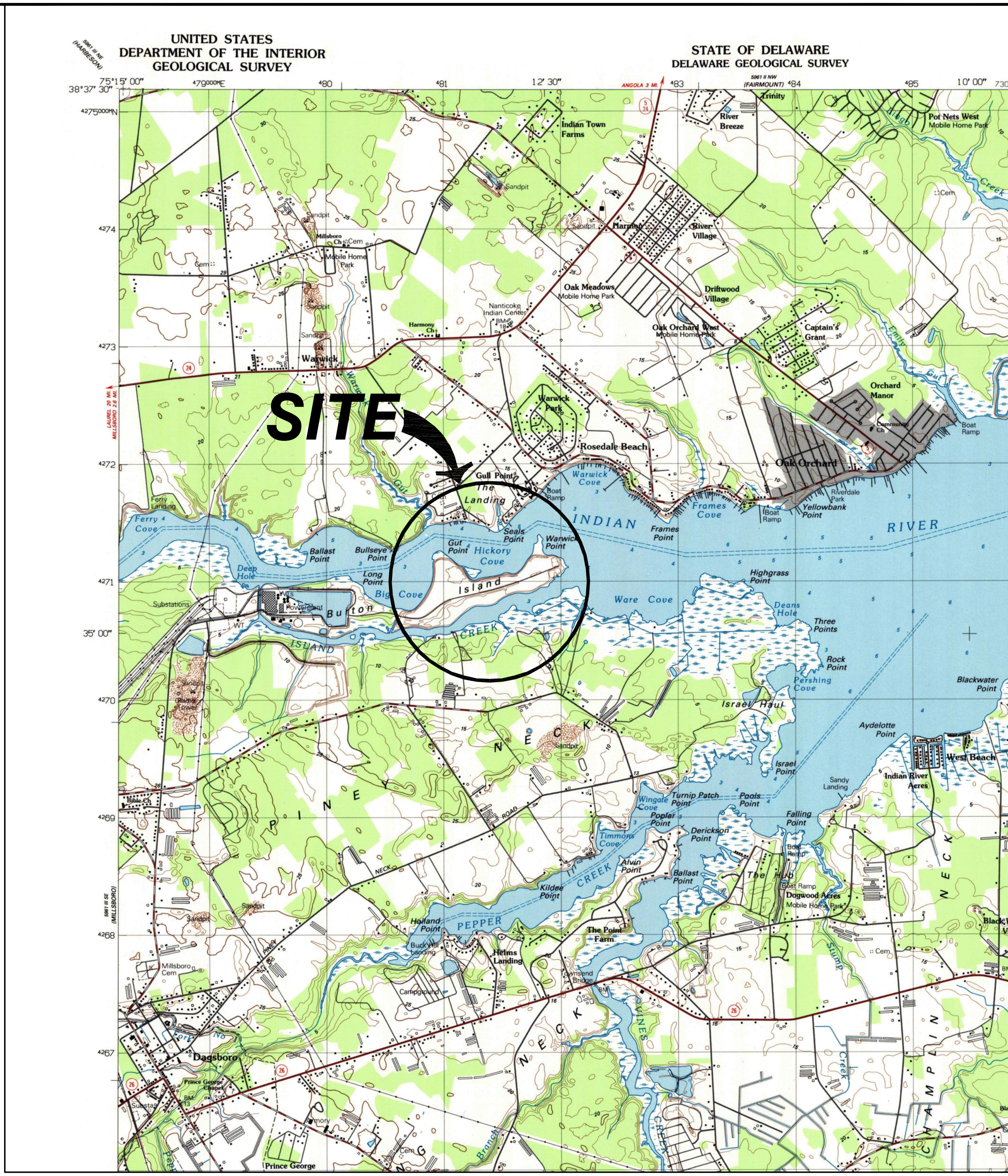
The Indian River Generating Station is located on Burton Island between the Indian River to the north and Island Creek to the south. The facility is located approximately four miles downstream and east of the Millsboro Dam at Millsboro, Delaware and approximately nine miles west of the mouth of the Indian River to the Atlantic Ocean. The site location is depicted in **Figure 1.1-1**. The facility consists of four coal-fired generating units with total capacity of 771 megawatt (MW). Units 1 and 2 are each 91 MW units and were placed in operation in 1957 and 1959, respectively. Unit 3 is 165 MW and was placed into service in 1970. Unit 4 is 424 MW and was placed into operation in 1980.

The Indian River Generating Station was sold by Delmarva Power & Light to NRG in June 2001. According to the Sussex County Tax Assessor's Map, the tax parcel 233-2.00-2 which includes the Ash Site, the active Indian River Power facility, rail access, and undeveloped land west of the main plant is 539.53 acres. A site map is presented on **Figure 1.1-2** for reference.

The area of the Ash Site is identified as 144.23 acres in previously published VCP documents. Since the time of purchase, NRG has not used this area for operational purposes. A site plan presented in the *Final Plan of Remedial Action, Burton Island Old Ash Landfill Site, Operable Units 1 and 3* dated August 5, 2008 shows the limits of the Ash Site. Site plans with and without an aerial photography background that depict this boundary are provided in **Figures 1.1-2** and **1.1-3**. However, the outline depicted in the site plans actually encompasses only 111.5 acres. The 144.23 acre value is inclusive of the land east of the operating facility security fence: the low-elevation narrow neck between the security fence and the higher elevation former ash management area, the higher elevation former ash management area, the intertidal zone of the shoreline, and the peripheral vegetated tidal marshes.

The following areas were determined through the AutoCAD drawing developed from plans prepared by professional licensed surveyors:

- The area of land (not including peripheral vegetated tidal marshes) east of the facility's cooling water intake and outfall is approximately 216 acres. [This value is similar to and consistent with the previously reported 214.86 acres for Burton Island].
- The area of land (not including peripheral vegetated tidal marshes) east of the facility's security fence is approximately 131.3 acres. [This value is similar to the 144.23 acres previously reported for just the Ash Site].
- The area of land (not including peripheral vegetated tidal marshes) east of the low-elevation narrow neck is approximately 111.5 acres. This is the area of the outline depicted as the Ash Site in the OU1 and OU3 Final Plan and figures in this report.



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REFERENCE:

7.5 MIN SERIES FRANKFORD QUADRANGLE, DELAWARE-SUSSEX COUNTY DATED 1991.

Shaw Environmental, Inc.

DESIGNED BY:	NRG - INDIAN RIVER FACILITY BURTON ISLAND SUSSEX COUNTY, DELAWARE
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DRAWN BY:	FIGURE 1.1-1
A. Yanavicius	SITE LOCATION MAP
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Shaw Shaw Environmental, Inc.

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DRAWN BY: DL/BBF	FIGURE 1.1-2			
CHECKED BY: A. Steele	FACILITY PLAN			
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REFERENCE: STREETMAP USA

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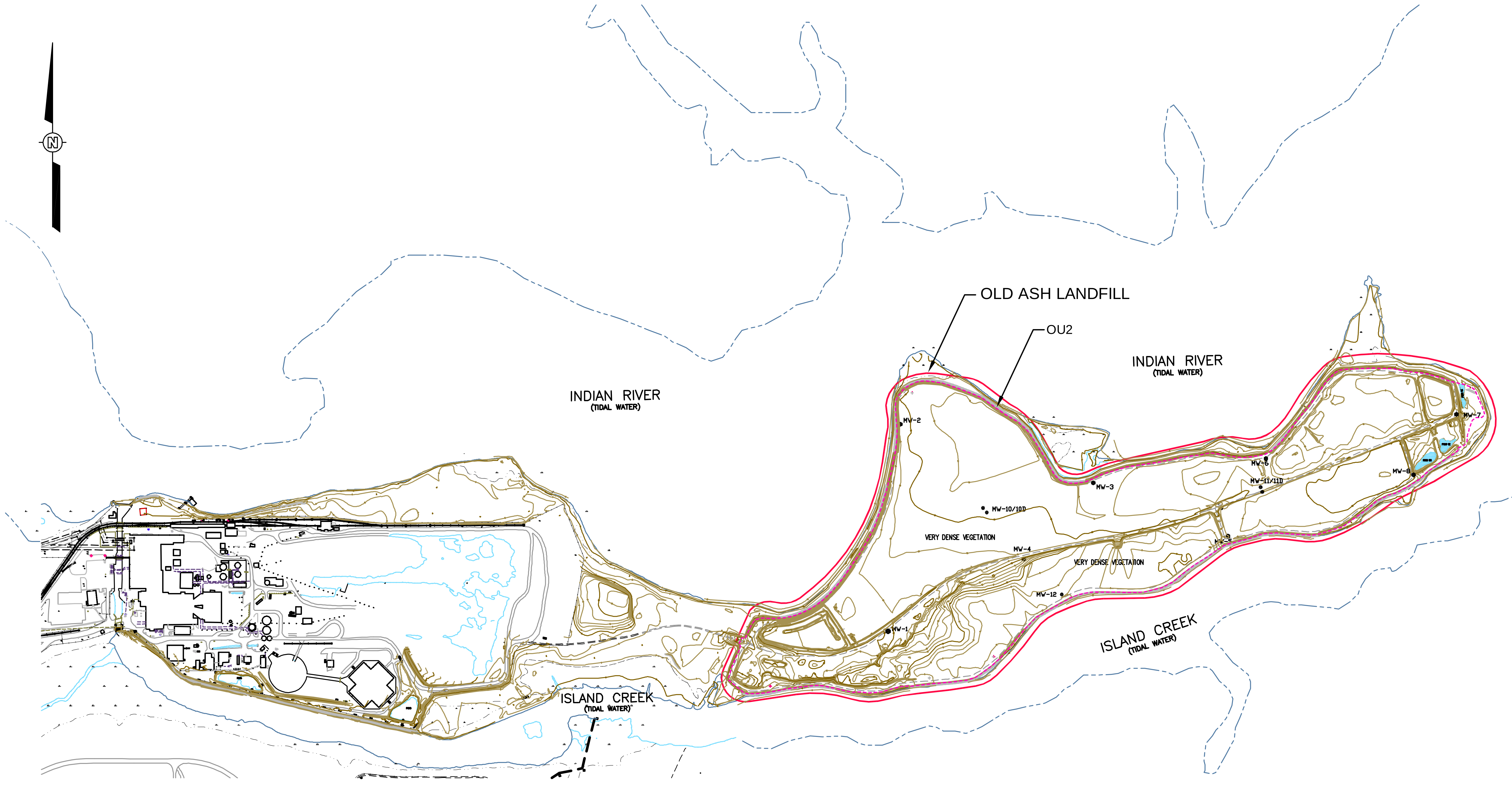

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REV	DESCRIPTION / ISSUE	DATE	APPROVED

DESIGNED BY: --	NRG - INDIAN RIVER FACILITY BURTON ISLAND SUSSEX COUNTY, DELAWARE
DRAWN BY: DL/BBF	FIGURE 1.1-3 SITE MAP
CHECKED BY: A. Steele	

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- The area of OU2, defined as the land areas landward (inside) of the footprint of the erosion control project, is approximately 93.6 acres. The OU2 boundary is depicted in **Figure 1.1-3**.

1.2 Facility History

Delmarva Power & Light purchased Burton Island in 1949 for the construction of the Indian River Generating Station. In the early 1950's, the eastern end of Burton Island was utilized by the Army Corps of Engineers for disposal of spoils dredged from the Indian River between the Millsboro Dam and the Indian River Inlet. Delmarva Power & Light began using the area for ash disposal when Unit 1 was placed in operation in 1957. Fly ash and bottom ash were sluiced to the portion of the island just beyond the operating power plant. Bottom ash was later removed and used to build roadways on the island. Fly ash was used to construct a perimeter berm system. Berms were constructed at a height of approximately 20 feet, consisting of approximately a 4 foot base of native soil, 14 feet of fly ash, and a 2 foot cap of bottom ash. By the mid 1960's the system of berms and access roadways was completed on the eastern end of the island. Fly ash was sluiced to the island through a 12-inch pipe. The pipe was moved between the north side of the center access road and the south side approximately every two years to distribute the fly ash to the various cells. Water decanted from the fly ash flowed into a settling pond near the tip of the island. Fly ash generated during power generation activities was deposited in this manner on Burton Island for a time period from approximately 1957 to 1979. With the start-up of Unit 4 in 1980, a new ash landfill was constructed and permitted to the south and across Island Creek from Burton Island. During the permitting of Unit 4 and the current ash landfill, the State of Delaware issued a letter defining requirements for the facility's operation of the Ash Site which were considered as operational standards. Since the time the current ash landfill became operational in 1980, ash generated at the facility for the four units has been deposited in the current ash landfill.

1.3 Previous Investigations

The FE was conducted in 2007, with field activities being implemented in May 2007. The FE report was submitted to DNREC in September 2007. The report discusses the nature and extent of the constituents of interest (COIs), as well as their fate and transport. The report also contains both a Human Health Risk Assessment and a Screening Level Ecological Risk Assessment (SLERA).

DNREC Site Investigation and Restoration Branch (DNREC SIRB) commented on the FE in a letter dated February 4, 2008. Their findings were as follows:

- The Facility Evaluation (FE), subject to detailed comments in the February 4, 2008 letter, is sufficiently detailed and comprehensive to serve as a RI for OU1 (shoreline sediments) and OU3 (offshore sediments and waters).
- The Screening Level for Ecological Risk Assessment (SLERA) states that the ash material and sediment at the Ash Site are not expected to adversely impact the shoreline and intertidal areas within the footprint of the proposed erosion control project, although it is also stated that there is a potential for adverse affects to benthic invertebrates in OU1. If designed and constructed properly, the proposed erosion control project along the shoreline should effectively remediate potential ecological exposures to the aquatic/riparian habitat by interrupting the pathways of exposure, thereby making further ecological risk assessment in this area unnecessary for the RI.
- The SLERA documents that ecological hazards are negligible in the areas riverward of OU1 and that no further ecological risk assessment is necessary for the RI in OU3.
- The FE is <u>not</u> sufficiently detailed and comprehensive to serve as an RI for OU2 (the area landward of OU1, *i.e.,* the former ash management area itself), and that additional work will be required for the RI on this OU.

The FE Report was revised in March 2008 at the request of DNREC to clarify a number of OU references within the document (no technical changes were made). On July 30, 2008, DNREC issued an *Approval of Final Plan of Remedial Action for Burton Island Ash Disposal Area (Operable Units 1 & 3)* (DNREC, 2008). This "Final Remedial Action Plan Approval" summarized DNREC's concurrence with the results of the FE for Operable Units 1 and 3 at the Ash Site and stipulated that additional investigation was warranted for OU2.

As presented in the February 4, 2008 comment letter, DNREC-SIRB's review of the FE for the Ash Site (Shaw, 2008) identified several data gaps in the risk assessments conducted for OU2. These data gaps, detailed in the following paragraphs, form the basis for the OU2 RI that is the subject of this report:

- The human health risk assessment did not assess potential exposures to ash material at OU2, which is the upland portion of the Ash Site itself. In order to fill this data gap, the recreational fisherman exposure scenario, which was quantitatively assessed in the FE (Shaw, 2008), will be expanded to include exposure to surface ash material via incidental ingestion and dermal contact.

Additionally, the human health risk assessment in the FE (Shaw, 2008) did not assess the potential exposures of off-site receptors being exposed to impacted groundwater or inhalation of wind-generated fugitive dust from OU2. If these exposure pathways are determined to be complete, then they will be quantitatively assessed

- The terrestrial food web models in the SLERA lacked site-specific area use factors (AUFs) and other site-specific habitat information that could be useful in refining the potential terrestrial food web interactions that were assessed in the SLERA. In order to fill this data gap, vegetation/habitat mapping of OU2 will be conducted.

- The community-level assessment and the terrestrial food web model for OU2 utilized soil samples collected at significant depths to characterize surface material and subsequent exposures. In order to fill this data gap, surface material (0 to 6 inch depth increment) will be collected and analyzed for chemical constituents. These data will also be used to characterize human exposures to surface material.

1.4 Purpose and Objectives

The purpose of this report is to present the results of the supplemental investigation of OU2 and to revise the human health and ecological risk assessments.

1.5 Report Organization

The remainder of this RI Report is broken out into six sections.

- Section 2 briefly discusses the physical characteristics of the site.
- Section 3 presents the nature and extent of the COIs including soil, pond surface water and sediment, and groundwater.
- Section 4 describes the air dispersion modeling process and output.
- Section 5 contains the Human Health Risk Assessment and the Ecological Risk Assessment.
- Section 6 presents the RI summary and associated conclusions.
- Section 7 contains references pertaining to the document and primarily the risk assessment.

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2.0 Environmental Conditions

The existing environmental conditions include physiographic, geologic, and hydrogeologic conditions as well as the surface features including wildlife, vegetative and habitat communities, wetlands, and surface water. The discussion in this section includes updates to previously reported site conditions based on data collected during this RI.

2.1 Physiographic Setting

Burton Island, which is actually a peninsula, is located approximately 3 miles east of Millsboro, Delaware along the Indian River and 9 miles west of the Atlantic Ocean. The Ash Site is bordered by the Indian River to the north and east, Island Creek to the south, and the Indian River Generating Station to the west. The Indian River flows to the east forming the Indian River Bay. Indian River Bay is a shallow drowned river valley system with freshwater inflow and a direct connection to the ocean through the Indian River Inlet, located within Delaware Seashore State Park. Both the Indian River and Island Creek are tidally influenced. However, much of the flow in Island Creek comes directly from the cooling water discharge of the generating station.

Cooling water for three of the station's four coal-fired stream-electric units is withdrawn from the Indian River via an intake canal and discharged to the facility discharge canal. Make-up water for the fourth generating unit is withdrawn from the discharge canal of the other three units. DNREC issued the original National Pollutant Discharge Elimination System (NPDES) permit to the station in 1977 and the permit is currently in a renewal phase. Water from Units 1, 2, and 3, and blowdown from Unit 4, are discharged via a canal into the upper reaches of Island Creek. Island Creek is a small tributary that empties into the Indian River downstream of the plant at Ware Cove. Because Indian River is influenced by tides from Indian River Bay, water from Island Creek enters Indian River and can be flushed back upstream in Indian River.

2.2 Geologic Conditions

The geology at the facility, as described in "Hydrogeologic Studies – 2005 Update", prepared by Michael Baker, Jr., Inc. (2006) for the Phase II Landfill Area (current ash landfill) to the south-southwest of Burton Island, is as follows:

The disposal site is underlain by the Columbia sand deposits (Pleistocene age) which blanket the entire central and southern portions of the State. These deposits range in thickness from less than 50 to over 125 feet in southern Delaware[1] and are comprised of predominantly medium-grained sand with varying mixtures of silt and gravel. In the Phase II Landfill Area (across Island Creek from Burton Island), the Columbia deposits are approximately 100 to 110 feet thick and have been found to consist of relatively homogeneous sand throughout their entire thickness. The Columbia deposits are generally classified as either SP-SM or SW-SM soils according to the United Soil Classification System which translates to moderately well-to-poorly sorted sand with minor amounts of silt.

Relatively deep test wells drilled for water production (wells A and B) a few hundred feet southwest of the currently active ash landfill encountered lenses or pockets of green silty clay interspersed with coarse sand below 110 feet[2]. These lenses have been assumed to mark the upper boundary of Miocene-age sediments at the site. The Miocene sediments generally consist of sand units interbedded with silty clay layers. According to Johnston (1972), the Miocene sands may directly underlie Pleistocene sands, making differentiation between the two difficult. Thus, some of the upper Miocene sands may have been identified at the site as Columbia deposits. However, it is apparent that silty clay is present below an elevation of approximately -75 to -90 feet relative to mean sea level (ft msl) in the site area.

While the geologic conditions underlying Burton Island have not been directly investigated below an elevation of approximately -35 ft msl, it is anticipated that the information discussed above for the Phase II Landfill Area is consistent with that underlying Burton Island.

2.3 Hydrogeologic Conditions

The hydrogeologic conditions in the area of Burton Island are described in more detail in Section 3.3 of this report. The results of a desktop informational search were provided in the Remedial Investigation Work Plan (RIWP) Addendum (Shaw, 2010) and were used to develop a conceptual site model (CSM). Additional data collected in accordance with the RIWP Addendum is used in this report to refine the CSM.

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[1] Johnston, R.H. 1973. Hydrology of the Columbia (Pleistocene) Deposits of Delaware: An Appraisal of a Regional Water Table Aquifer. Delaware Geological Survey, Bulletin No. 14.

[2] Gilbert Associates, Inc. 1976, 1989. Design Plan for the Environmentally Safe Disposal of Coal Ash, Indian River Power Generating Station. Report submitted to the Delaware DNREC by Delmarva Power and Light Company.

2.4 Environmental Setting

This section includes a discussion of wildlife, vegetative and habitat communities, wetlands, and ponds.

2.4.1 Wildlife

In preparation for the multiple phases of shoreline stabilization activities on Burton Island, the U.S. Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), and the Delaware Natural Heritage and Endangered Species Program were requested to provide information as to the possible presence of threatened and endangered species in the vicinity of the shoreline stabilization project. Except for aquatic species, the species identified for the shoreline stabilization project area (which included both shoreline and upland construction support areas) also apply to other areas of OU2. Therefore, this wildlife and habitat information was considered for the ecological risk assessment detailed in Section 5.2.

The responses from the USFWS indicated that, except for occasional transients, no proposed or federally listed endangered or threatened species were known to exist within the shoreline stabilization project area. The NMFS responses indicated that several species of sea turtles including loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempi*) and green sea turtle (*Chelonia mydas*) may be found in the Indian River near Burton Island. A review of the Delaware Natural Heritage and Endangered Species Program database indicated that there are currently (as of September 2010) no records of state-rare or federally listed plants, animals or natural communities within the shoreline stabilization project area. The Delaware Division of Fish and Wildlife Fisheries Section indicated that although there are species of concern present in the river system, they are not likely to be impacted by the shoreline stabilization project. Burton Island does not lie within a State Natural Heritage Site nor does it lie within a Delaware National Estuarine Research Reserve.

DNREC does have records of black vulture (*Coragyps atratus*) in the vicinity of the Burton Island, but according to DNREC "this species should not be impacted unless the forested portion of the parcel is going to be disturbed. In addition, there are two bald eagle nests upstream and trees along the shore are likely utilized for roosting and foraging" (DNREC, 2007).

In addition to the site-specific wildlife data presented in the next section, a species checklist for the nearby Assawoman Wildlife Area (AWA) shows that the following mammals may be present in the area:

- White-tailed Deer
- Grey Squirrel
- Delmarva Fox Squirrel
- Southern Flying Squirrel
- Eastern Cottontail
- Raccoon
- Striped Skunk
- Red Fox
- Gray Fox
- River Otter
- Muskrat
- Meadow Vole
- Eastern Mole
- Masked Shrew
- White-footed Mouse
- Cotton Rat

The AWA data also include 162 species of birds, 12 species of reptiles and 12 species of amphibians (Gano, 1996).

2.4.2 Vegetative and Habitat Communities

To supplement the environmental data collected in support of the FE (Shaw, 2008), a vegetative cover and habitat survey was conducted in OU2. The survey was conducted in accordance with the approach identified in the RIWP (Shaw, 2010a). This investigation included a desktop review of existing information and mapping followed by a detailed field identification of the varying vegetative communities and associated habitats.

2.4.2.1 Field Survey Preparation

In preparation for the field survey, a desktop review of existing information was performed. The existing aerial and topographic maps were reviewed to identify major surface features and potential habitat boundaries. File reviews from USFWS, NMFS, and Delaware Natural Heritage and Endangered Species Program provided records of species historically found in the area of the site. Published documents were also reviewed to help determine the likelihood of encountering threatened and endangered and/or invasive plant communities on Burton Island.

2.4.2.2 Field Survey Methodology

A field survey was performed by two teams of two personnel traversing OU2 on foot on transects set on an approximately 200 foot grid during the week of October 19, 2009. The field survey teams were accompanied by Robert Coxe, an ecologist with the Delaware Natural Heritage Program, on October 21, 2009. The field survey confirmed the cover types and ecological habitats identified by desktop review and identified specific vegetation and growth habits for the major vegetative species identified on Burton Island.

Sampling plots were established at each grid node encompassing a 10-foot radius around the node. The plots were located by global positioning system (GPS) for precision mapping and photo documented. The percent aerial coverage and vertical growth of each vegetative stratum within each sample plot was determined (based on visual assessment of *absolute* cover in each of three stratum: tree/canopy [>20 feet in height], shrub/understory [3 to 20 feet in height], and herbaceous/groundcover [0 to 3 feet in height]) and the dominant species within each stratum were identified. Observations were recorded at each grid node on field data sheets as well as general commentary of observations walking between nodes.

An inventory of the vegetation at each transect was the initial guide to the identification of habitat types. Supported by the aerial maps, the boundaries of the different ecological communities were delineated in the field as they were crossed by each transect. Wetlands, areas of open water, other sensitive environments, and areas of exposed ash material were identified in the field and mapped.

The field survey was conducted in accordance with the approach identified in the RIWP (Shaw, 2010a); however, a GPS reading at each grid node was not possible in the more densely vegetated areas. The coordinates were used to guide field crews to specific locations on the grid. In lieu of the GPS data, field crews used professional judgment and existing site features to approximate their positions for data collection. Select transects were modified during the field survey where large areas of monoculture vegetative/habitats were observed in that field data forms were not completed. Specific grid nodes were traversed by field crews but no form was completed within a monoculture vegetative/habitat.

2.4.2.3 Results

The field survey results indicate that the habitats and species observed were as expected based on the desktop review. The vegetation and wildlife species observed on Burton Island during this survey are listed in the tables provided in **Appendix A**. There were seven (7) types of vegetative/habitat communities identified by Shaw in OU2 as detailed in **Table 2.4-1**. The Shaw habitat communities were compared to those identified in the "Guide to Delaware Vegetation Communities, Spring 2009" report prepared by Delaware Natural Heritage. The comparable guide vegetative communities are identified in the Community Notes in the below table. The wetland indicator status (U.S. Department of Agriculture [USDA] Natural Resource Conservation Service [NRCS] Region 1) and the native/exotic classification are identified for each species in the vegetation listing of **Appendix A**. The aerial extents of the various communities are depicted on **Figure 2.4-1**.

Table 2.4-1

Vegetative and Habitat Communities of OU2

Vegetative/Habitat Community	Other Vegetative Species Observed	Grids	Community Notes
Blackberry*, Dominated 20 to 90%, Upland (BBU)	• Loblolly • Black cherry • Common reed* • Groundsel tree • Goldenrod	• A19, A20 • B20, B21 • C18 • H3	• "*Northeastern Successional Shrubland*" • Typically very dense herbaceous coverage 75 – 90% • No visible exposed ash
Black Cherry Dominated 25 – 70%, Upland (BCU)	• Mexican fireweed • Goldenrod • Loblolly • Blackberry • Common reed*	• A21 • B19, B23 • C19, C20	• "*Successional Maritime Forest*" • Generally good herbaceous coverage 45 – 90% • No visible exposed ash
Black Locust Mix Dominated 5 – 70%, Upland (BLM)	• Common reed* • Loblolly • Bush lespedeza* • Groundsel tree • Asiatic tearthumb* • Japanese stilt grass* Other common species but not dominant: • Bayberry • American holly • Persimmon	• D12, D13, D14, D15 • E11, E12, E13, E14 • F10, F11, F12 • G6, G7, G8 • H4, H5, H6	• "*Black Locust Forest*" • Typically 2 to 3 inches of organic material • Some visible/exposed ash only observed on trees that were downed, on exposed root system.
Bayberry/Red Maple Dominated 25-100%, Wetland/Transition (BRM)	• Loblolly • Common reed* • American holly • Sweet gum • Persimmon	• E15 • F13, F14, F15 • G10, G11, G12, G13, G14 • H9, H10 • I9 • J8	• "*Wax Myrtle Shrub Swamp*" • Generally little herbaceous coverage 0 – 15%, due to dense canopy • Typically 2 to 3 inches of organic material • No visible exposed ash • Several areas of downed large trees and shrubs, which altered vegetation
Loblolly/Common Reed Mix Dominated 25 – 100%, Upland (LPH)	• Bayberry • Groundsel tree • Hercules club • Mexican fireweed • American holly	• C21, C22, C23 • D16, D17, D18, D19, D20, D21 • E16, E17, E18, E19, E20 • F5, F16	• Generally few plant species in the herbaceous layer (<3 feet) • Area dominated with common reed, which is typically >3 feet in height • Typically 2 to 3 inches of organic material • No visible exposed ash
Bayberry/Loblolly Dominated 50 – 100%, Upland (BLO)	• Black cherry • Common reed*	• A22 • B8 • C6, C7, C8, C9 • D6, D7, D8, D9, D10 • E5, E6, E7, E8, E9, E10 • F6, F7, F8, F9	• "*Loblolly Pine/Wax Myrtle*" • Generally little herbaceous coverage 0 – 15%, due to dense canopy • Typically 2 to 3 inches of organic material • No visible exposed ash

Table 2.4-1 (continued)

Vegetative and Habitat Communities of OU2

Vegetative/Habitat Community	Other Vegetative Species Observed	Grids	Community Notes
Common Reed* Dominated >25%, Upland (SOF)	• Groundsel tree • Bush clover • Hercules club • Loblolly • Black cherry • Blackberry* • Bayberry • Mexican fireweed • Persimmon • Witch grass • Red fescue • Japanese stilt grass* • Crown vetch	• B6, B7, B18, B22 • G4, G5, G9 • H7, H8 • I1, I2, I3, I4, I5, I6, I7, I8 • J1, J2, J3, J4, J5, J6, J7	• Successional old field to shrubland • Generally the area is densely vegetated

Note: Italicized community notes are similar descriptions to the vegetation communities described in "Guide to Delaware Vegetation Communities, Spring 2009".
* Denotes an invasive species.

In addition to identifying the vegetative and habitat communities, the field survey also included recording observations of areas of exposed ash where vegetation was not established. In general, there was little to no exposed ash observed. Two primary areas of exposed ash were identified and are associated with previous monitoring well installation and construction support areas; the other areas were relatively small, narrow, access road related and/or thinly covered with leaf litter. The areas of exposed ash that were observed measured in total approximately 1 acre of 93.6 acres. The larger areas of exposed ash are depicted on **Figure 2.4-1**.

The exposed ash areas include the following:

- Cinders and exposed ash were observed in patches along the steep side slopes south of the centerline road. The areas were very steep, greater than 45 percent slopes, with somewhat unstable banks and when the leaf litter was disturbed, cinders and ash were visible.
- Both bare ground (i.e., sand) and patches of a sand and cinders mixed were visible in the vicinity of groundwater monitoring well MW-4 and east along the centerline road where vegetation has previously been cleared for access to the monitoring well (shown on **Figure 2.4-1**).
- Cinders and exposed ash were observed on the side slopes of a V-shaped depression located north of the centerline road on the western end of OU2 (shown on **Figure 2.4-1**).
- Exposed ash was observed in the trench in the depression at the western point of OU2.
- A staging area on the western end of OU2 utilized for the ongoing shoreline stabilization project had been cleared of vegetation two years prior, some of which was growing back. Both bare

ground (i.e., sand) and patches of a sand and ash mix were visible in this former staging area (shown on **Figure 2.4-1**).

- Cinders were observed in a small area (< 9 square feet) on the shoreline stabilization project access road located due west of the northeast tidal inlet/pond.
- Cinders were observed in a small area (< 9 square feet) within the bermed area directly north and west of the southwest freshwater pond.
- Typically areas of sparse herbaceous vegetation were in areas of very dense canopy cover and contained 2 to 3 inches of organic material coverage. These areas were generally within the undisturbed dense stands of bayberry and black locust. These areas are not included in the listing of exposed ash presented above.

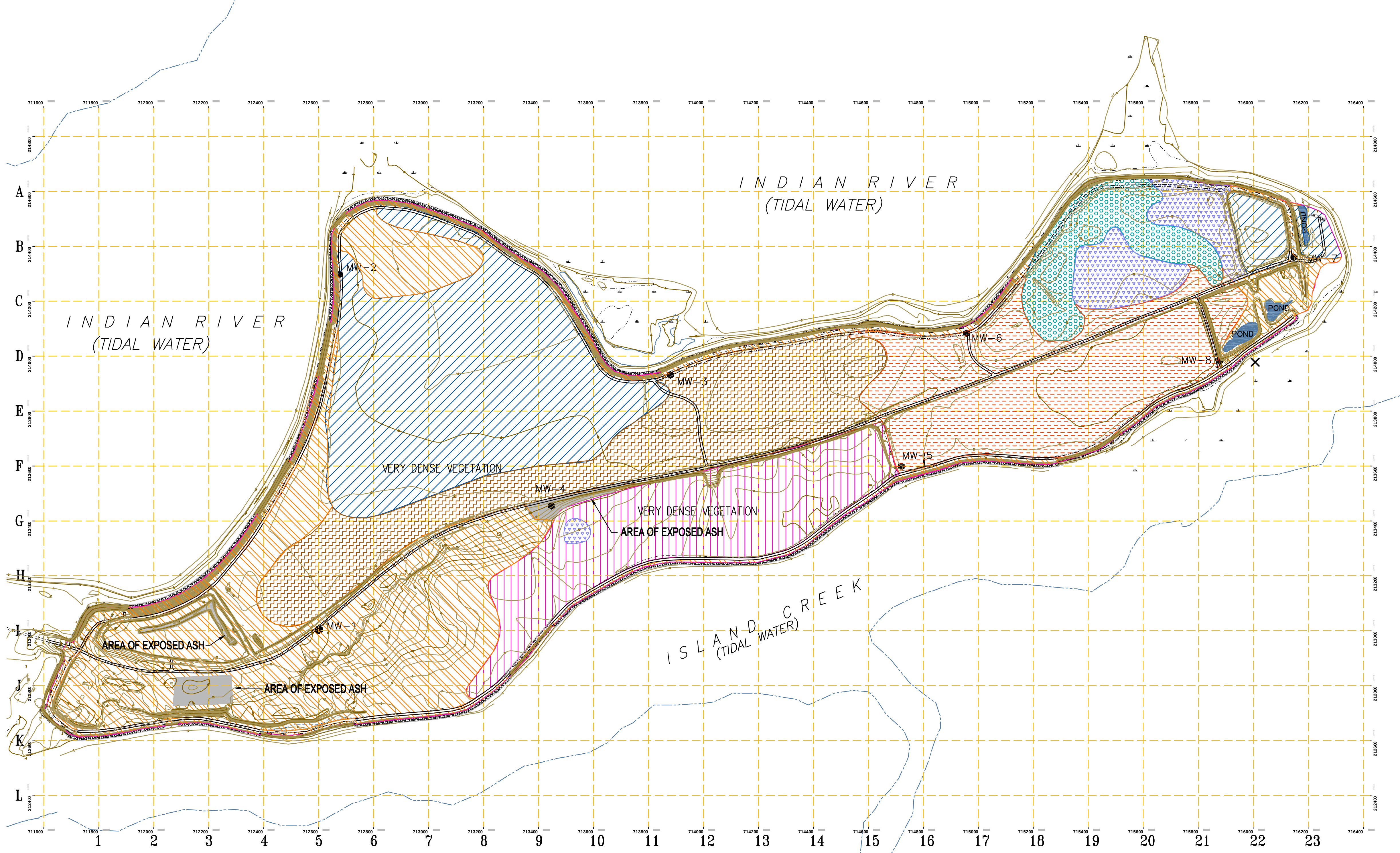
In summary, OU2 is primarily vegetated with very limited areas of exposed ash (1%) and three surface water ponds. The breakdown of the 93.6 acres of OU2 area is summarized in **Table 2.4-2**. The breakdown includes the area of access roads that are not vegetated nor are they bare ash.

Table 2.4-2

Percent Cover of OU2 by Vegetative and Habitat Community

Cover Type	Area (square feet)	Area (acres)	Percent Cover
BBU	167,659	3.8	4.1%
BCU	148,791	3.4	3.6%
BLO	855,616	19.6	21.0%
BLM	568,077	13.0	13.9%
LPH	577,226	13.3	14.2%
SOF	1,186,034	27.2	29.1%
BRM	461,018	10.6	11.3%
Exposed Ash	45,834	1.1	1.1%
Ponds	12,570	0.3	0.3%
Access Roads	54,391	1.2	1.3%

OFFICE	DRAWING NUMBER
Trenton, NJ	19684028-D1



LEGEND:

- BBU–BLACKBERRY DOMINATED 20 to 90%, UPLAND (area–167659 sq ft)
- BCU–BLACK CHERRY DOMINATED 25–70%, UPLAND (area–148791 sq ft)
- BLO–BAYBERRY/LOBLOLLY DOMINATED 50–100%, UPLAND (area–855616 sq ft)
- BLM–BLACK LOCUST MIX DOMINATED 5–70% UPLAND (area–568077 sq ft)
- LPH–LOBLLOY/COMMON REED MIX DOMINATED 25–100% UPLAND (area–577226 sq ft)
- SOF–SUCCESSIONAL OLD FIELD TO SHRUBLAND, DOMINATED WITH >25% COMMON REED, UPLAND (area–1186034 sq ft)
- BRM–BAYBERRY/RED MAPLE DOMINATED 25%–100% WETLAND/TRANSITION (area–461018 sq ft)
- ASH (area–45834 sq ft)
- INSTALLED RIP RAP REVETMENT FOR SHORELINE STABILIZATION
- OU2 AREA BOUNDARY
- POND (TOTAL AREA–12570 sq ft)
- ACCESS ROAD

NOTE:

COORDINATE GRID IS IN DELAWARE STATE PLANE NAD83 (IN FT)

SCALE 0 200 400 FEET

REV	DESCRIPTION / ISSUE	DATE	APPROVED

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NRG - INDIAN RIVER FACILITY
BURTON ISLAND
SUSSEX COUNTY, DELAWARE

FIGURE 2.4-1
VEGETATIVE AND HABITAT COMMUNITIES
OCTOBER 2009

DESIGNED BY:	DRAWN BY:	CHECKED BY:	APPROVED BY:	DATE:	SCALE:	DRAWING NO.	SHEET NO.
--	A. Yanavicius	D. Page	A. Steele	11/29/10	AS SHOWN	19684028-D1	--

XREF Files: IMAGE Files:
File: \\PITTFP2\d\Data\Drafting\cad\Shaw Offices - CAD Files\Stoughton, MA\NRG\Indian River\19684028-D1.dwg
Plot Date/Time: Dec 21, 2010 - 8:41am
Plotted By: bernadette.oconnor

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2.4.3 Wetlands

A tidal wetland study was conducted between September 27, 2005 through October 1, 2005 to determine the extent of State and Federal regulated wetlands, tidal water and subaqueous lands on the shoreline of the Burton Island peninsula. The study area included the shoreline from the facility's water intake/outfall structure to the eastern tip of the peninsula. The wetlands identified and delineated for this study were mostly restricted to coves and vegetated flats along the perimeter of Burton Island. The wetlands were delineated in accordance with the *Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory 1987) (Manual). The delineation utilized a comparison of different vegetative communities, soil sampling to identify the presence or absence of hydric soils, and the determination of presence, potential presence, or absence of wetland hydrology. Subsequent review was conducted by the DNREC-Wetlands in association with the ongoing shoreline stabilization project. In addition to the 2005 shoreline wetland study, any wetland areas observed on the interior of OU2 were documented during the October 2009 vegetation and habitat field survey (described in Section 2.4.2). The October 2009 field survey was not, however, a formal wetland delineation effort.

The wetland resources identified at the Ash Site are limited to the shoreline outside the perimeter ash berms, the ponds on the eastern tip of the peninsula, and the bayberry/red maple dominated wetland/transition area on the south-central portion of OU2. The shoreline wetland delineation closely follows the OU2 boundary. The ponds and the immediate area of the ponds are wetlands within the OU2 boundary and are described in more detail in Section 2.4.4. Based on the description of the ponds provided in Section 2.4.4, the ponds and the immediate area of the ponds would likely be classified as E1US4M or E1US3M (estuarine, subtidal, unconsolidated shore, organic or mud, and irregularly exposed). Estuarine is a tidal wetland. The wetland/transition area identified in Section 2.4.2.3 is also located within the OU2 boundary as depicted on **Figure 2.4-1**. The vegetative characteristics of this area are summarized in **Table 2.4-1**. Based on the vegetation and habitat notes collected during the October 2009 field survey, this wetland/transition area would likely be classified as a combination of PSS1 (palustrine, scrub-shrub, broad-leaved deciduous) and PFO1 (palustrine, forested, broad-leaved deciduous). Palustrine is a freshwater wetland.

The shoreline wetland delineation is consistent with the State wetland maps. In accordance with definitions provided by the USFWS, the shoreline wetlands of the study area were classed within the Estuarine system and the Intertidal subsystem, in which the substrate is exposed and flooded by tides, including any associated splash zone. Specifically, the study area wetlands were classed as Estuarine Intertidal Emergent (E2EM), Estuarine Intertidal Scrub/Shrub (E2SS), and Estuarine Intertidal Forested (E2FO).

The E2EM wetlands in lower landscape positions (saltmarshes) were dominated by saltmarsh cordgrass. (The saltmarshes established below the mean high tide line and inundated by the diurnal tides were classified within the Subtidal subsystem. These areas were located below the mean high tide line and were categorized as "subaqueous lands.") The upper reaches of the wetlands (saltmeadows) were dominated by a more diverse vegetative assemblage. Common herbaceous plants in this habitat included common reed, saltmeadow cordgrass, saltgrass, saltmarsh bulrush, black grass, slender glasswort, sea lavender, seabeach orach, seashore mallow, marsh mallow, seaside goldenrod, and saltmarsh fleabane.

The E2SS wetlands were dominated by marsh elder (especially along the saltmarsh – saltmeadow interface), groundsel bush, southern bayberry, common greenbriar and poison ivy.

The E2FO wetlands were established in the most landward landscape positions in areas sheltered from wind. The trees forming the canopy of the forested wetlands included loblolly pine, box elder, water oak, sweet gum and black gum. The understory was comprised of species such as American holly, sweetbay magnolia, southern bayberry and Devil's walking stick.

The transition zone between the wetland and upland habitats was colonized by many species, including loblolly pine, eastern red cedar, black cherry, beach plum, oaks (water, southern red, willow and pin), groundsel bush, southern bayberry, silk tree, sassafras, cat greenbriar, poison ivy and common reed.

2.4.4 Surface Water/Ponds

In accordance with the RIWP (Shaw, 2010a), the site-specific investigation of the three surface water ponds within the footprint of OU2 included qualitative evaluations regarding whether the ponds are contiguous with Island Creek/Indian River or are isolated, whether they are perennial or ephemeral, and whether the pond sediment is consistent with the shoreline and near-shore sediments characterized in the FE (Shaw, 2008). The evaluation also included a description of vegetation associated with the ponds, signs of ecological receptors using the ponds; and presence or absence of fish, herpitiles, and/or other ecological receptors. The ponds are designated by relative location on the eastern tip of the Burton Island peninsula as Pond SW (southwest), Pond SE (southeast) and Pond NE (northeast) as shown in **Figure 2.4-2**. The *in situ* water quality parameters including pH, temperature, conductivity, dissolved oxygen, turbidity, oxidation-

OFFICE *Trenton, NJ*

DRAWING NUMBER 19684028-B1

SCALE

0 120 240 FEET

LEGEND:

MW–8 ⬢ MONITORING WELL LOCATION

■ POND SURFACE WATER AND SEDIMENT LOCATION SAMPLE

Shaw® Shaw Environmental, Inc.

REV	DESCRIPTION / ISSUE	DATE	APPROVED

DESIGNED BY: --	NRG - INDIAN RIVER FACILITY BURTON ISLAND SUSSEX COUNTY, DELAWARE
DRAWN BY: *DL/BBF*	FIGURE 2.4-2
CHECKED BY: *A. Steele*	POND LOCATIONS

APPROVED BY:	DATE:	SCALE:	DRAWING NO.	SHEET NO.
--	12/16/10	AS SHOWN	19684028-B1	--

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Image: Burton_Island_extract_2.sid
indian river-2.tif
Plot Date/Time: Dec 22, 2010 – 3:43pm
Plotted By: greg.jones

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reduction potential (ORP), salinity, and total dissolved solids (TDS) as measured in the ponds on July 21, 2010 are shown in **Table 2.4-3.** The analytical results for surface water and sediment samples collected from these three ponds are discussed with Nature and Extent in Section 3.2.

Table 2.4-3

Pond Surface Water *In Situ* Parameters

Water Quality Parameter	Pond SE	Pond SW	Pond NE
pH	8.44	7.66	7.26
Temperature (^{0}C)	28.1	29.9	31.1
Conductivity (mS/cm)	52.2	18.0	62.5
Dissolved Oxygen (mg/L)	7.51	8.52	2.95
Turbidity (NTU)	165	3.50	4.5
ORP (mV)	100	20	-248
Salinity (%)	3.55	1.07	4.00
TDS (g/L)	32	11	37

^{0}C – degrees Celsius
mS/cm – milli-Siemens per centimeter
mg/L – milligrams per Liter
NTU – Nephelometric Turbidity Units
ORP (mV) – oxidation-reduction potential measured in millivolts
TDS (g/L) – total dissolved solids measured in grams per Liter

Pond SW – Pond SW is located within a bermed area and measures approximately 160 feet in length and approximately 50 feet wide. The surrounding berms are continuous and there is no visible direct surface water connection to Island Creek. The pond appeared to be at about the same elevation as Island Creek. The 5-10 foot wide mud flats observed around the pond indicate a low tide condition matching the tide stage in the adjacent tidal waters and indicating a possible communication between the tidal waters and the pond. However, no drain pipe was visible on the Island Creek side or on the pond side of the berm separating the Pond SW from Island Creek. The *in situ* water quality parameters for Pond SW (**Table 2.4-3**) indicate a salinity of 1.07 percent. This is brackish water of lower salinity than the adjacent Island Creek tidal waters (1.5 to 2.5 percent salinity based on the July 2010 tidal study data) indicating limited communication between Pond SW and Island Creek. The water depth at the time of the survey was quite shallow (less than 1 foot), but the pond appeared to be permanent and not ephemeral. The dissolved oxygen concentration was 8.52 milligrams per Liter (mg/L) and the *in situ* turbidity was 3.5 Nephelometric turbidity units (NTU). The dominant plant species surrounding the pond is *Phragmites australis* (common reed). The width of the Phragmites zone is approximately 30 feet on the north side of the pond and 5 feet on the south side. Damselflies and large horseflies were observed on reed stubble in the pond. The tracks of deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*) and wading birds were present in the mud surrounding the pond. A medium sized (approximately 5 inch) blue-claw crab (*Callinectes sapidus*) was observed in the pond as well as numerous minnows, likely *Fundulus* sp. The mud in and adjacent to the pond was visually evaluated and appeared to be native material. However, cinders were noted in a depressed area directly north and west of Pond SW during the Burton Island vegetation survey.

Pond SE – Pond SE is located a short distance to the east of Pond SW. There is no apparent communication between the two ponds. Pond SE is approximately 115 feet in length and 70 feet in width. The water of Pond SE was noticeably green in color and turbid at the time of the evaluation, and the pond bottom could not be seen in order to estimate water depth. The *in situ* turbidity value was quite high at 165 NTU. Pond SE appeared to be a permanent water body, and communication with the tidal water of Island Creek is likely occurring at least during spring tides via a low area at the end of the berm at the east end of the pond. The water of Pond SE had a dissolved oxygen concentration of 7.51 mg/L and a salinity of 3.55 percent, somewhat higher than the average salinity of the adjacent Island Creek tidal waters (based on the July 2010 tidal study data). Evaporation occurring between spring tide periods may account for the higher salinity of Pond SE. Groundsel bush (*Baccharis halimifolia*), a facultative species common in higher portions of salt marshes, was present in the berm to the south of the pond and elsewhere in the vicinity. Other vegetation surrounding Pond SE included marsh elder, (*Iva frutescens*), common reed (*Phragmites australis*) and cord grasses. The band of Phragmites surrounding Pond SE is narrow on the Island Creek side and wider to the north. A green heron (*Butorides virescens*) was observed perched on shrubby vegetation near the pond. Raccoon tracks were present in the sediment surrounding the pond. The sediment was a muddy sand which appeared to be native material. No ash or cinders were observed in the pond shoreline sediment. An old nest with eggshell fragments, likely mallard, was observed on the south shore of the pond. Deer tracks and wading bird tracks were seen in the sediment adjacent to the pond to the east. Fiddler crab (*Uca* sp.) burrows were present in the sediments at the east end of the pond, and several small fiddler crabs were observed. No minnows were observed in Pond SE but the water was very turbid and their presence could not be ruled out.

Pond NE – Pond NE is located to the north and east of Pond SE. Pond NE is long and narrow, approximately 150 feet long and 25 feet wide. Pond NE appears to be a permanent salt pond that communicates with the Indian River during spring tides. Although the tide stage was low, no mud flat was present around Pond NE. The water of Pond NE was turbid (4.5 NTU), but not noticeably green as was Pond SE. The water of Pond NE had somewhat low dissolved oxygen concentration (2.95 mg/L) and a salinity of 4.00 percent, significantly higher than that of the adjacent Indian River estuary (based on July 2010 tidal study data) and higher than average ocean salinity (3.5 percent). Evaporation occurring between spring tide periods may account for the elevated salinity. The bottom substrate of Pond NE was soft black mud which appeared to be native material. A small area (several square feet) of what appeared to be cinders or bottom ash was observed on the west bank of the pond. There is a narrow fringe of *Spartina alterniflora* around the pond, with the *Spartina* extending to the north towards the Indian River. Other vegetation observed adjacent to Pond NE included marsh elder and groundsel bush. A little Blue Heron (*Egretta caerulea*) was observed perched in a tree adjacent to the pond. Numerous 1 to 3 inch minnows, likely *Fundulus* sp., were seen in the pond.

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3.0 Nature and Extent of Constituents of Interest at OU2

The nature and extent of COIs related to the Ash Site has been defined through previous investigations and supplemental investigations of OU2. The current RI sampling activities included the collection of surface and subsurface soil samples from within OU2, soil samples from drilling cores, surface water and sediment samples in ponds, and groundwater samples from monitoring wells. The current RI activities also included a tidal gauging study. The following sections describe the nature and extent of COIs as defined through these activities. Each section also contains a description of the activities themselves.

3.1 Surface and Subsurface Soil

The objectives of the soil characterization were as follows:

1. Characterize the physical and chemical composition of the surface (0 to 0.5 ft below ground surface [bgs]) and subsurface (2 to 3 ft bgs) material at OU2 for more accurate exposure estimates in the human health and ecological risk assessments.
2. Characterize the physical and chemical composition of the surface material for use in the air dispersion modeling exercise.
3. Characterize the physical and chemical composition of the surface and subsurface material at OU2 to help determine the effect of natural processes (physical, chemical, and biological) on the ash material at the ground surface (0 to 0.5 ft bgs) compared to the subsurface (2 to 3 ft bgs).

3.1.1 Coal Source Data Review

Historical coal procurement records identifying the source(s) of coal utilized at the facility at the time ash was being deposited at the Ash Site were not available. However coal specifications, boiler design documentation, and current facility knowledge indicates that the coal used at the facility while the Ash Site was in operation was always eastern bituminous. This determination was further verified by operating permits and operational specifications as the units were designed to only utilize this fuel type. As such, the record search did not reveal any information indicating that additional trace contaminants should be added to the analyte list which contains TAL metals (inclusive of mercury and cyanide), uranium, and thorium.

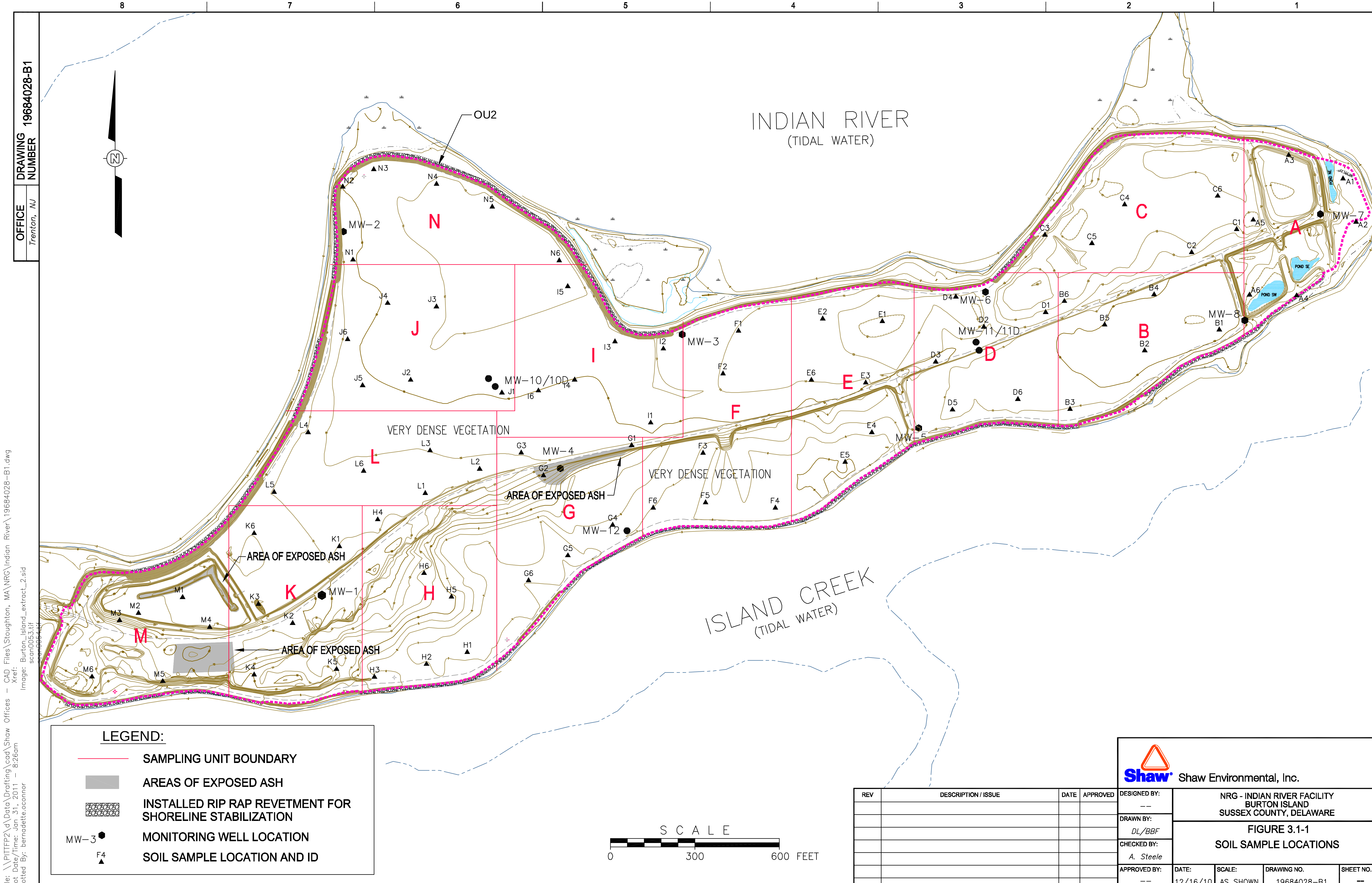
3.1.2 *Soil Sampling Approach*

The sampling strategy selected for OU2 is Three Stage Sampling using compositing. As described in the RIWP, the sampling approach for the RI employed fourteen (14) large sampling units of approximately (7) acres each. Note that at the time the RIWP was prepared and the sampling performed, the area of OU2 was incorrectly assumed to be 144 acres. And, thus, the sampling units were assumed to be 10 acres each. The number of samples was not changed from that proposed in the RIWP. Thus, since the area of OU2 is actually 93.6 acres, the sampling performed resulted in each sample representing a smaller area than planned.

Six randomly distributed sampling points were established for each approximate seven-acre area from which six (6) surface (0 – 0.5 ft bgs) samples and six (6) subsurface samples (2 to 3 ft bgs) were collected. An 8-oz portion of each sample was collected in a glass jar and stored on site and additional volume was collected for compositing and submittal to the laboratory. Thus, fourteen (14) surface soil composite samples were collected, one from each area; and fourteen (14) subsurface soil composite samples were collected, one from each area, for a total of twenty-eight (28) composites. **Figure 3.1-1** is a map of OU2 which delineates the fourteen (14) 7-acre areas and the 6 sampling points within each sampling unit.

The location of each subsample was planned to be located with a GPS; however, consistent satellite signals were not obtained while working in the vegetated areas. The field crews instead placed a pin flag at each sampling location for potential future identification. The surface samples were collected with a stainless steel spoon while the subsurface samples were collected from a depth of two to three feet using a hand auger. Each sample was submitted to Test America Laboratory in Edison, New Jersey and analyzed by the offsite laboratory for the following analytes and properties:

- target analyte list (TAL) metals by U.S. Environmental Protection Agency (USEPA) SW-846 Method 6020 with mercury by USEPA SW-846 Method 7471A and cyanide by USEPA SW-846 Method 9012A;
- total organic carbon (TOC) by Lloyd Kahn Method;
- grain size by American Society for Testing and Materials (ASTM) D422;
- density by ASTM D2937;
- pH by USEPA SW-846 Method 9045C; and
- percent moisture by ASTM D2974-87.



Shaw Shaw Environmental, Inc.

REV	DESCRIPTION / ISSUE	DATE	APPROVED

DESIGNED BY: --
DRAWN BY: DL/BBF
CHECKED BY: A. Steele
APPROVED BY: --

NRG - INDIAN RIVER FACILITY
BURTON ISLAND
SUSSEX COUNTY, DELAWARE

FIGURE 3.1-1
SOIL SAMPLE LOCATIONS

DATE: 12/16/10 | SCALE: AS SHOWN | DRAWING NO. 19684028-B1 | SHEET NO. --

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At the request of DNREC, three each of the surface soil and subsurface soil composite samples were analyzed by the offsite laboratory for uranium and thorium.

Soil samples were screened in the field for gamma radioactivity using a Ludlum Model 19 MicroR ratemeter. Readings were obtained at waist height and at the ground surface at each sampling location prior to disturbing the surface. Readings were also obtained of each subsample collected. In addition, five (5) areas in the AWA, Piney Point Tract located approximately one mile southeast of Burton Island were also screened for gamma radioactivity.

The soil characterization effort was conducted in accordance with the methodology detailed in the RIWP (Shaw, 2010a).

3.1.3 Sampling Results

The soil sampled during the surface and subsurface field investigation were predominantly ash with sand cover. The ash was consistently very fine grained, gray, dry, and loose. The physical characteristics of each sample from the ground surface to 3 feet below ground surface are identified in the summary tables provided in **Appendix B**. No biological inclusions (e.g., shells, bones, etc.) were observed in any sample.

3.1.3.1 Radioactivity

Naturally-occurring radioactive materials (NORM) are prevalent and ubiquitous in the soils of the United States (USEPA, 2010a). Coal combustion residue can contain some trace elements that are naturally radioactive including uranium and thorium. However, coal fly ash is not regulated by USEPA for its radioactive constituents primarily because of the low concentrations and limited potential for exposure. Radioactivity was evaluated in this RI through field screening of gamma radiation for health and safety purposes and through laboratory analysis of uranium and thorium activity in select soil samples.

A Ludlum Model 19 MicroR ratemeter was used to conduct a field survey for gamma radiation during sampling activities for the sole purpose of evaluating health and safety procedures in sample handling. Surface and one meter exposure rate readings were made at each soil sample location. The surface readings ranged from 8 to 29 microR per hour (μR/hr) and the readings taken at 1 meter from the surface ranged from 6 to 24 μR/hr. Individual samples collected from the surface (0-6") and subsurface (2'-3') were also screened and the results ranged from 10 to 12 μR/hr. The exposure rate measurements for each sample are summarized in the **Table B-1** provided in **Appendix B**. The recorded readings were low, within the range expected for fly ash, and below the action levels. Therefore, no additional health and safety measures, alternate shipping/transport requirements, nor alternate laboratory handling procedures were triggered.

As requested by DNREC, the Ludlum Model 19 MicroR ratemeter was also used to conduct a field survey for gamma radiation at the offsite background reference location, the AWA. Five (5) locations were selected a few meters off the road and where the ground was exposed such that no digging or removal of leaf litter was required to obtain a measurement at ground surface. The readings ranged from 5 to 6 μR/hr. These readings are similar to the 'background' measurements of 7 μR/hr recorded during the daily instrument response check performed in the field support trailer staged at the current ash landfill.

The isotopic uranium and thorium results for OU2 soil samples are summarized in **Table B-2** in **Appendix B**. The uranium and thorium results indicate that the radioactivity levels in the OU2 soil samples are within the range expected for bituminous coal ash (USEPA, 2010a) as summarized in **Table 3.1-1** below. Therefore, the OU2 soil would not be regulated by USEPA for its radioactive constituents. Based on these results, no further investigation of the radiological characteristics of the soils is recommended. It is important to note that the Delaware URS for 'uranium (soluble salts)' is not comparable to the isotopic uranium results.

Table 3.1-1

Comparison of Radioactivity Levels in OU2 Soil Samples and Bituminous Coal Ash

	Thorium (pCi/g)			Uranium (pCi/g)		
	228	230	232	234	235	238
OU2 Soil Samples, 95% UCL of the Mean	2.56	3.09	2.50	3.09	0.14	3.00
Bituminous Coal Fly Ash [a]	3.0	5.1	3.0	5.1	--	5.1
Bituminous Coal Bottom Ash [a]	2.4	4.1	2.4	4.1	--	4.1

[a] USEPA, 2010a
pCi/g – pico-Curies per gram
UCL – Upper Confidence Level
-- - not reported

3.1.4 Nature and Extent of COIs in Soil

The analytical results for the soil samples are summarized in tables provided in **Appendix B**. Surface sample and subsurface sample geotechnical results are in **Tables B-3 and B-4**, respectively. Surface sample and subsurface sample metals and various wet chemistry parameters results are in **Tables B-5 and B-6**, respectively. The laboratory report is provided at the end of **Appendix B**.

3.1.5 Statistical Analysis for Homogeneity

Statistics were used to compare the surface (0-6") and subsurface (2'-3') data sets for TAL metals. The objectives were to determine 1) if the surface material is homogeneous throughout

OU2, 2) if the subsurface material is homogeneous throughout OU2, and 3) if any significant differences exist between the surface material and subsurface material. The findings are summarized in the following sections. A more detailed discussion of the statistical comparison and supporting data are provided in **Appendix C**.

3.1.5.1 Test of Differences Between Surface Material and Subsurface Material

Analytical data were compared to determine whether concentrations of each TAL metal in surface (0 to 6 inch depth interval) and subsurface (2 to 3 feet depth interval) material are statistically different. Concentrations of metals in surface and subsurface samples were evaluated using goodness-of-fit tests as described in the ProUCL Version 4.0 software (USEPA, 2007a, b). Where both of the data sets for a TAL metal were normally distributed, the Student T-test, a parametric test, was used to test for the equality of mean concentrations in each material. Where either one or both of the data sets for a TAL metal were not normally distributed, the Wilcoxon Rank Sum (WRS) test, a non-parametric test, was used to test for the equality of median concentrations. In addition, a series of box and whisker plots were generated to visually evaluate the data sets.

Silver and cadmium were not detected in any sample and were not considered in the statistical analysis. Similarly, cyanide was not detected in enough samples to make a statistical comparison. The analytical results and statistical analyses support the conclusion that detected metal concentrations in surface and subsurface materials are not statistically different with 95% confidence.

3.1.5.2 Homogeneity of Surface Material and Subsurface Material

The analytical results and statistical analyses support the conclusion that both the surface and subsurface concentrations are homogeneous with respect to aluminum, arsenic, barium, beryllium, chromium, copper, iron, lead, thallium, vanadium, zinc, and mercury.

The box and whisker plots of surface material indicate potential high outlier concentrations of magnesium, potassium, selenium and sodium. Potential high outlier concentrations were identified in subsurface material for antimony, calcium, magnesium, and manganese.

ProUCL 4.0 provides for more detailed statistical analysis of potential outliers using the Dixon test which is applied to data sets of less than 25 data points. The software guidance cautions that decisions about outliers should be in the context of other evaluations and should not be based on statistical analysis alone. The risk assessment is provided in Section 5 of this report.

None of these concentrations exceed the 75th percentile by a factor of 10, suggesting that these statistically high concentrations may be associated with the low number of samples (14) and the low variability observed in many of the measurements. The outlier concentrations were detected in a variety of samples within the data set and are generally not co-located. More than one outlier concentration was detected in only two composite samples.

It is concluded that both surface and subsurface materials are generally homogeneous with respect to metals concentrations.

3.2 Pond Surface Water and Sediment

The small ponds on the eastern end of OU2 were investigated during the RI field work conducted in July and August, 2010. The surface water and sediment of the ponds was sampled on July 21, 2010. The qualitative ecological characterization of the ponds was conducted on August 2, 2010.

3.2.1 Sampling Rationale

The RIWP states that two "ponded" areas in the southeastern corner of OU2 are to be included on the investigation, and if any additional semi-permanent or permanent surface water features are found within OU2 during the vegetation mapping or surface material characterization tasks, those additional surface water features will be characterized in a similar fashion as the characterization described below for the two "ponds" in the southeastern corner of Burton Island. Prior to the field investigation, it was determined that a third pond is present on the northeastern tip of OU2. This third pond was subsequently included in the investigation. As stated in the RIWP, the investigation was conducted in order to characterize the surface water and sediment in these ponds and to determine whether the condition of the surface water and sediment in these ponds is consistent with the condition of the surface water and sediment in the adjacent Indian River and Island Creek. Sample collection consisted of one sediment sample and one surface water sample from each of the three ponds. In addition, *in situ* field measurements of surface water parameters were collected from each of the ponds. The sampling locations within the three ponds, designated Pond NE, Pond SE and Pond SW are shown on **Figure 2.4-2**.

3.2.2 Sampling Results

The sediment and surface water analytical results in pond samples collected on July 21, 2010 are presented in summary tables provided in **Appendix D**. The laboratory report is included at the end of **Appendix D**. The *in situ* field data were discussed previously in Section 2.4.4.

3.2.3 Nature and Extent of COIs in Pond Surface Water and Sediment

COIs in sediment and surface water for the ponds were identified by comparing sediment and surface water analyte concentrations with DNREC URS and Delaware default background remediation standards. These values are shown in the **Table D-1** and **Table D-2** in **Appendix D**. Detected concentrations that are greater than URS or background standards are considered COIs, and are shown in bold in the tables. The COIs were further evaluated by comparing the concentrations found in pond sediment and pond surface water samples to concentrations found in shoreline and offshore sediment and surface water samples collected from the perimeter of Burton Island for the FE (Shaw, 2008). These concentration ranges are also shown in the tables. Statistical tests were performed to determine if significant differences in surface water and sediment parameter concentrations (WRS test), or average concentrations (t-test) exist between concentrations found in the FE and concentrations found in the ponds. The data for the single surface water and sediment samples from each pond are assumed to represent surface water and sediment conditions for the entire pond.

Pond SE – Seven COIs were identified in Pond SE sediments: arsenic, barium, beryllium, iron, selenium, thallium and vanadium. Seven COIs were identified in Pond SE surface water: aluminum, arsenic, barium, iron, lead, selenium and vanadium.

Pond SW – Eleven COIs were identified in Pond SW sediments: aluminum, antimony, arsenic, barium, beryllium, copper, iron, nickel, selenium, thallium and vanadium. Nine COIs are identified in Pond SW surface water: aluminum, arsenic, barium, copper, iron, lead, manganese, selenium and vanadium.

Pond NE - Nine COIs were identified in Pond NE sediments: aluminum, barium, beryllium, copper, iron, manganese, nickel, selenium, and vanadium. Four COIs were identified in Pond NE surface water: arsenic, barium, manganese and selenium.

3.2.3.1 Pond Sediment COIs

Sediment aluminum concentrations in the ponds exceeding screening values were 18,400 milligram per kilogram (mg/kg; Pond SW) and 21,300 mg/kg (Pond NE), which are similar in magnitude but higher than the maximum aluminum concentration in sediments found during the FE (18,200 mg/kg). Sediment antimony concentrations ranged from undetected to 1.6 mg/kg, a value less than the URS but greater than the Delaware default background concentration of <0.5 mg/kg. Antimony was not detected in sediment samples collected during the FE. Arsenic concentrations greater than screening values in pond sediments were 24.6 mg/kg in Pond SE and 112 mg/kg in Pond SW. These are within the range of sediment arsenic concentrations in FE samples (1.6 mg/kg to 160 mg/kg). Barium concentrations exceeding screening values ranged from 52 mg/kg to 139 mg/kg. These concentrations are within the range of barium sediment concentrations found in the FE. Beryllium concentrations exceeding screening values in pond sediments ranged from 0.68 to 2.4 mg/kg. The range of sediment beryllium concentrations found in the FE was 0.08 to 1.9 mg/kg. Copper concentrations in pond sediments exceeding screening values were 36.6 mg/kg in Pond NE and 44.5 mg/kg in Pond SW. Sediment copper concentrations found during the FE ranged from 0.99 to 39.4 mg/kg. Iron concentrations exceeding screening values in pond sediment ranged from 6,160 to 26,400 mg/kg. These are well within the range of sediment iron concentrations found during the FE, where the highest iron concentration was 34,900 mg/kg. Manganese exceeded sediment screening values in Pond NE (200 mg/kg). This is within the range of sediment manganese concentrations found during the FE. Nickel concentrations in pond sediments exceeding screening values were 22.0 mg/kg at Pond NE and 28.5 mg/kg at Pond SD. Nickel concentrations in sediments reported in the FE ranged from 0.73 to 26.0 mg/kg, slightly below the highest pond concentration. Selenium concentrations in pond sediments exceeding screening values ranged from 2.0 to 10.2 mg/kg, which is approximately twice the highest concentration found during the FE (4.9 mg/kg). Thallium sediment concentrations exceeded screening values at Pond SE (1.9 mg/kg) and Pond SW (3.3 mg/kg). Thallium was detected in only one sediment sample collected during the FE at a concentration of 2.8 mg/kg. Vanadium concentrations in pond sediments ranged from 25.5 (Pond SE) to 82.5 mg/kg (Pond SW). The concentration found in Pond SW is less than twice the highest FE sediment concentration (43.3 mg/kg).

Statistical tests including the t-test and the WRS test were used to determine if significant differences in concentrations exist between concentrations of parameters identified as COIs in pond sediments and concentrations of these parameters in sediment samples collected for the FE. The results of the statistical analysis are presented in **Table 3.2-1**.

Of the twelve pond sediment COIs, the concentrations of antimony, arsenic, barium, iron, manganese, nickel, and thallium were found to be not significantly different from concentrations in FE sediment samples in statistical tests where a result could be obtained. The concentrations of two COIs, aluminum and selenium, were found to be significantly different from concentrations in FE sediment samples in statistical tests where a result could be obtained. The results obtained for sediment concentrations of copper and vanadium were not consistent between the two statistical tests.

Table 3.2-1

Statistical Comparison of COI Concentrations in Pond Sediment and FE Sediment

Pond Sediment COI	t-test	WRS Test
Aluminum	Significantly Different	Significantly Different
Antimony	NA – Numerous NDs	Not Significantly Different
Arsenic	Not Significantly Different	Not Significantly Different
Barium	Not Significantly Different	Not Significantly Different
Beryllium	Not Significantly Different	Not Significantly Different
Copper	Significantly Different	Not Significantly Different
Iron	Not Significantly Different	Not Significantly Different
Manganese	Not Significantly Different	Not Significantly Different
Nickel	Not Significantly Different	Not Significantly Different
Selenium	NA – Numerous NDs	Significantly Different
Thallium	NA – Numerous NDs	Not Significantly Different
Vanadium	Not Significantly Different	Significantly Different

NA – Not Applicable
The t-test results for antimony, selenium, and thallium are listed as "Not Applicable" due to the high number of non-detected values.

3.2.3.2 Pond Surface Water COIs

Pond surface water concentrations of aluminum exceeding screening values were 1,850 micrograms per Liter (µg/L) at Pond SW and 2,680 µg/L at Pond SE. These are within the range of surface water aluminum concentrations found during the FE. Arsenic concentrations exceeded screening values in all three ponds and ranged from 7.2 µg/L in Pond NE to 327 in Pond SW. The maximum surface water arsenic concentration found during the FE was 14.4 µg/L. Barium concentrations in the three ponds were 35.9 µg/L in Pond NE, 103 µg/L in Pond SE and 304 µg/L in Pond SW, all exceeding screening values. The two higher concentrations exceeded the maximum barium surface water concentration found in the FE (73.4 µg/L). Copper concentrations exceeded screening values in Pond SE and Pond SW (30.2 and 37.7 µg/L respectively). The maximum copper concentration found in FE surface water samples was 16.5 µg/L. Iron concentrations exceeded screening values in Pond SE and Pond SW (2,090 and 4,030 µg/L respectively). These are within the range of surface water iron concentrations found in the FE. Lead concentrations exceeded the URS value of 3 µg/L in Pond SE and Pond SW (3.2 and 3.7 µg/L respectively), but not the Delaware background standard of 15 µg/L. Lead was detected in one of eight FE surface water samples at a concentration of 2.9 µg/L. Manganese concentrations exceeded screening values in Pond NE and Pond SW (75.4 and 90.6 µg/L respectively). These are within the range of manganese concentrations found in FE surface water samples. Selenium concentrations exceeded the URS screening value of 0.4 µg/L in all three ponds, at concentrations ranging from 6.0 µg/L (Pond SW) to 11.9 µg/L (Pond SE). However, these concentrations are below the Delaware background standard of 20 µg/L. Selenium was not detected in surface water samples collected during the FE effort. Vanadium surface water concentrations exceeded screening values in Pond SW and Pond SE (21.1 and 22.7 µg/L respectively). These values are only slightly above the 19.0 µg/L screening value. Vanadium was detected in only one FE surface water sample at a concentration of 9.4 µg/L.

Statistical tests including the t-test and the WRS test were used to determine if significant differences exist between concentrations of parameters identified as COIs in surface waters of the ponds and concentrations of these parameters in surface water samples collected for the FE. The results of the statistical analysis are presented in Table 3.2-2.

Of the nine pond surface water COIs, the concentrations of aluminum, barium, copper, iron, lead and manganese were found to be not significantly different from concentrations in FE surface water samples. The pond water concentrations of three COIs, arsenic, selenium and vanadium, were found to be significantly different from FE surface water samples in statistical tests where a result could be obtained.

Table 3.2-2

Statistical Comparison of COI Concentrations in Pond Surface Water and FE Surface Water

Pond Surface Water COI	t-test	WRS Test
Aluminum	Not Significantly Different	Not Significantly Different
Arsenic	Significantly Different	Significantly Different
Barium	Not Significantly Different	Not Significantly Different
Copper	Not Significantly Different	Not Significantly Different
Iron	Not Significantly Different	Not Significantly Different
Lead	NA - Numerous NDs	Not Significantly Different
Manganese	Not Significantly Different	Not Significantly Different
Selenium	NA - Numerous NDs	Significantly Different
Vanadium	NA - Numerous NDs	Significantly Different

NA – Not Applicable
The t-test results for lead, selenium, and vanadium are listed as "Not Applicable" due to the high number of non-detected values.

3.3 Groundwater

A groundwater investigation was conducted to supplement data collected during the FE (Shaw, 2008) and these data were used to assess the water bearing zones in the region around Burton Island and the connectivity between groundwater under OU2 and both the surface water and local drinking water aquifer. The groundwater investigation included a desktop information search, monitoring well installation, groundwater sampling, and a tidal study. The result is a revised CSM and estimate of mass loading of COIs to the surrounding surface water bodies of Indian River and Island Creek.

3.3.1 Initial Conceptual Site Model

The initial description of the CSM was presented in the RIWP Addendum (Shaw, 2010b) and is summarized here to set the stage for information being provided in the subsequent sections. Based on data from previous soil borings, the Ash Site on Burton Island is comprised of approximately 10 to 22 feet of coal combustion bottom ash and fly ash overlying sands and gravels of the Pleistocene age Columbia sand aquifer. The thickness of ash decreases from west to east across Burton Island and is not present at the eastern end of the peninsula. The drill logs for some of the monitoring wells installed on Burton Island show a thin bed (less than one foot thick) of decomposed organic matter between the bottom of the ash and top of natural materials. This layer likely represents the vegetation on Burton Island that was buried when the ash was sluiced into the Ash Site. The Columbia sand aquifer is approximately 110 feet thick in the vicinity of the Indian River Generating Station as described in Section 2.2.

The base of the Columbia sand aquifer is marked by the transition from sand and gravel to lenses or pockets of green silty clay interspersed with coarse sand. The top of this zone represents the top of Miocene age sediments as is reported to occur below -75 ft msl in the vicinity of Burton Island. The deepest test borings that have been drilled at the Ash Site for installation of monitoring wells have only been drilled to an elevation of -36 feet relative to mean sea level and did not encounter the fine grained Micocene lenses or pockets. The top of the Micocene sediments can be considered an aquitard forming the base of the Columbia sand aquifer. As the Columbia sand sediments will be relatively more conductive than the top of the Miocene sediments.

Both the ash and underlying coarse grained sediments of the Columbia aquifer are relatively conductive; therefore, they are considered one hydrogeologic unit - an unconfined aquifer. Based on water level data obtained in May 2007, ash occurs below the water table in some areas and is saturated. As the thickness of ash thins from west to east, so does the zone of saturated ash.

The surface water bodies that surround the peninsula, Indian River and Island Creek, are tidally influenced. Additionally, Island Creek is influenced by cooling water discharges from the facility. Due to these factors, the water levels in Indian River and Island Creek are constantly changing. The initial CSM presented in the RIWP Addendum depicted a water table configuration within the peninsula that was responding to tidal fluctuations. Three plausible depictions of the water table and directions of groundwater flow were put forth as part of the initial CSM. These included depictions of inward flow during high tide and outward flow during low tide. Outward flow was presented under two conditions depending on the height of mounding of the water table in the central portion of the peninsula, one with low relief mounding and one with a relatively high relief mounding. Under the low relief mounding scenario, groundwater would discharge laterally to Indian River and Island Creek, but with little propensity to move downward into the shallow aquifer. Under the high relief mounding scenario, groundwater would move laterally towards Indian River and Island Creek, but would also have a greater potential to move downward into the Columbia sand aquifer.

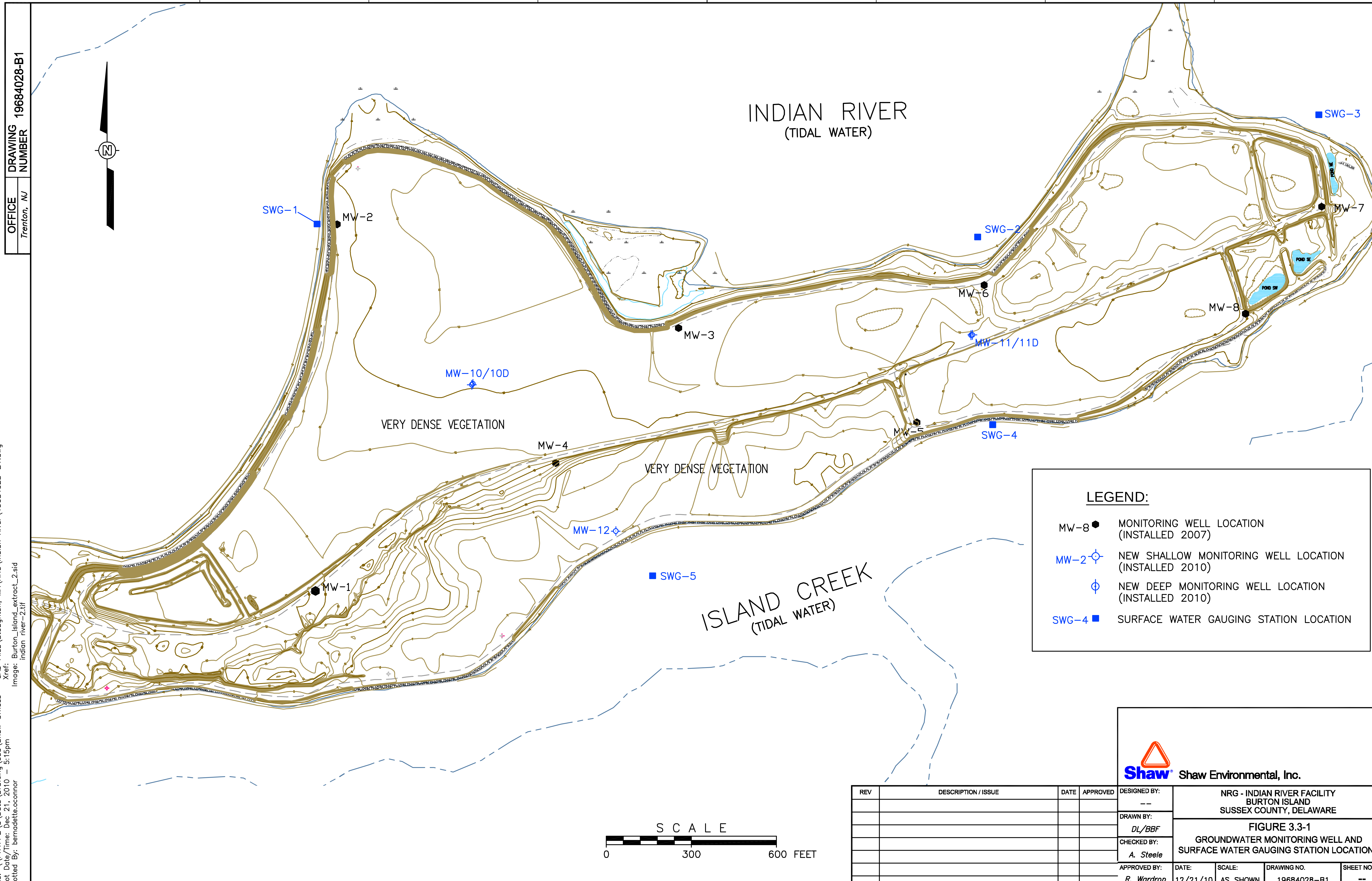
Based on this initial CSM, Shaw designed a tidal study to determine groundwater flow characteristics over a series of tidal cycles.

3.3.2 Installation of New Monitoring Wells

Two new monitoring well nests (each comprised of one shallow well and one deep well) and one additional shallow well (total of five new wells) were installed as part of the groundwater investigation. Greg Decowsky and Steve Johnson of DNREC observed installation activities on July 8, 2010 including well pad completion and a tour of the drill rig. The three shallow wells (MW-10, MW-11, and MW-12) were installed and constructed similar to the shallow wells installed as part of the FE in 2007 (MW-1 to MW-9). The new and former well locations are shown in **Figure 3.3-1**. Prior to well installation at each location, a continuous soil boring was advanced using a track-mounted direct-push technology drill rig (Geoprobe™ 8040DT). Written logs of the subsurface materials sampled at each new monitoring well and monitoring well construction details were kept by Shaw's field inspector and these are included in **Appendix E**.

Once the lithology in each boring was logged, the exact screen interval was selected and well installation proceeded. At DNREC's request, the subsurface materials immediately above and immediately below the ash/native material interface were sampled and sent to an analytical laboratory for TAL Metals analysis. A select subset of these samples was also sent to an analytical laboratory for uranium and thorium analysis. The analytical laboratory reports are included in **Appendix E**.

In general, ten-foot screen intervals were set at the top of the uppermost aquifer, across the interval between 15 and 25 ft bgs, dependent upon the drill log. The two deeper wells (MW-10D



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Plot Date/Time: Dec 21, 2010 - 5:15pm
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Image: Burton_Island_extract_2.sid
indian river-2.tif
Plotted By: bernadette.oconnor

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and MW-11D) were installed in similar fashion with ten-foot screen intervals, the tops of which were generally located 15 ft below the bottom of the shallow well screens in each nest. In general, each of the screens in the deeper monitoring wells spans an interval between 40 and 50 ft bgs.

Each monitoring well was constructed using two-inch inner diameter polyvinyl chloride (PVC) pre-packed well screens and riser pipe. The top of the pre-packed screen sections feature a five-foot long section of solid PVC riser, surrounded with a pre-packed bentonite collar. The Geoprobe™ unit was used to advance 4.5-inch drill rods with an expendable point to a depth consistent with the bottom of the screened interval, as determined by the soil boring log. The well string was lowered down the inside of the drill rods until it reached the bottom of the boring. The rods were then retracted to a level just above the top of the bentonite collar as the pre-packed bentonite collar expands quickly in water and has a potential to wedge inside the drill rods if too much time passes before pulling the rods up. Potable water was poured into the drill rods to wet the bentonite collar if it was not lowered below the water level in the test boring at the time of installation. A bentonite slurry was mixed and placed in the annular space of the well to complete the well seal to the surface. A steel protector casing with locking cap was set into a concrete well pad to complete each installation. The stick-ups of the steel protector casings were set at approximately 3 ft above ground surface. At the completion of each installation the monitoring well was developed using a peristaltic pump. Each well was developed for a period of approximately 30 minutes, until the discharge was clear.

Single well hydraulic testing in the form of slug tests were performed at the five new monitoring wells to derive values of hydraulic conductivity (K) for the aquifer underlying Burton Island. The slug tests were conducted using a PT2X Aquistar® brand pressure transducer and a reusable stainless steel slug. Both slug-in and slug-out test were conducted. The monitoring well to be tested was first gauged for static water elevation and total depth in order to determine the proper placement of both the pressure transducer and slug. The pressure transducer was inserted into the well and secured at a constant distance from the top of the well casing. The height of the water column above the pressure transducer was noted prior to insertion of the slug. The slug was then rapidly inserted into the water column and real-time readings were used to monitor the height of the displaced water column above the pressure transducer over time and the water level recovered towards the initial static position. When real-time transducer readings indicated that the water column had fallen back to its initial height above the pressure transducer, the test was stopped and data were downloaded to a lap-top computer. The procedure was then repeated as the slug was removed from the well in order to conduct a rising head slug test. The stainless steel slug and transducer were decontaminated between monitoring wells using Liquinox® detergent and distilled water.

The data collected from the slug tests were analyzed using Aqtesolv® slug test analysis software. The transducer data were plotted as displacement over time and K values were determined using the Unconfined Bouwer-Rice solution that was visually fitted to the plotted data. Slug test analysis sheets for each test are provided in Appendix H.

3.3.3 Tidal Study

The tidal study was performed in order to ascertain a more accurate and more detailed CSM. The objective of obtaining this updated CSM was to determine the pathways of COI migration in groundwater and mass loading of COIs to Indian River and Island Creek from OU2. In preparation for the test, Shaw installed five new groundwater monitoring wells described in Section 3.3.2 to add to the existing network of nine monitoring wells (total of 14 monitoring wells), and established five temporary surface water monitoring stations. Thirteen monitoring well locations (excluding background well MW-9, located west of the facility) and the five surface water monitoring locations are shown on **Figure 3.3-1**. The five surface water monitoring stations (SWG-1, -2, -3, -4, and -5) and seven of the monitoring wells (MW-2, -6, -10, -10D, -11, -11D, and -12) were fitted with continuous recording devices that collected water level, temperature, and specific conductance measurements at ten minutes intervals over the duration of the test. The test was conducted from July 13, 2010 through August 2, 2010. A protocol was established to extend the test if one or more storm events caused unusual fluctuations in surface water levels as compared to the magnitude of normal tidal fluctuations. No such storms occurred during the tidal study and there was no need to extend the test.

3.3.3.1 Surface Water Monitoring Stations

Each of the five surface water gauging stations (SWG-1 through SWG-5) was constructed of sections of 1-inch diameter galvanized steel pipe, joined together with threaded couplings. The pipe was driven five feet into the river sediments with a manual fence post driver from a boat. One-half inch holes were drilled into the section of pipe within the water column, to allow the water to equalize with tidal change within the pipe. A sensor connected to a data logger (CTD Diver, manufactured by Schlumberger Water Services) was set within each surface water monitoring station pipe, to continuously monitor the water level, conductivity, and temperature fluctuation over the duration of the tidal study.

3.3.3.2 Determination of Water Level Elevations

CTD Diver continuous recording devices were set in monitoring wells MW-2, MW-6, MW-10, MW-10D, MW-11, MW-11D, and MW-12, and in the five surface water monitoring stations (SWG-1 through SWG-5). The CTD Diver records pressure head at programmed time intervals. The programmed time interval for this deployment was 10 minutes. Pressure head readings were measured by setting the CTD Diver sensor below the water level in each well at approximately midway in the screened interval.

For purposes of analyzing water level data collected over the course of the tidal study, pressure readings were converted to water level elevations relative to mean sea level. Details concerning the conversions are provided in **Appendix F**. Pre-tidal study and post-tidal manual water level measurements were used to establish values for cable length (the distance from the top of casing measuring point to the sensor on the pressure transducer). Cable length is used in the conversion of pressure head data to water level elevation data.

The pre-tidal study and/or post-tidal manual water level measurements for wells MW-11 and MW-11D were determined to be inaccurate and the value for cable length could not be derived with confidence for these two wells. The manual water level measurements may have been inaccurate due to moisture in the PVC riser above the actual static water level.

As such, the pressure head data collected for MW-11 and MW-11D could not be converted to water level elevation data with confidence. The variation in total pressure head measurements for MW-11 and MW-11D were useful is estimating the magnitude of water level fluctuations that were occurring at these wells during the tidal study and specific conductance and temperature data were collected for these two wells. In addition, surface water monitoring station SWG-3 malfunctioned thirteen hours after installation and did not record any water level, specific conductance, or temperature data thereafter.

In summary, full water level elevation, specific conductance, and temperature data were collected from monitoring wells MW-2, MW-6, MW-10, MW-10D, and MW-12 and from surface water monitoring points SWG-1, SWG-2, SWG-4, and SWG-5 throughout the entire nineteen day tidal study. Full pressure head, specific conductance and temperature data sets were collected for monitoring wells MW-11 and MW-11D. These data were sufficient to derive a much more detailed and robust CSM of the groundwater flow system at Burton Island presented in Section 3.3.5.

3.3.4 Results

Observational data were collected during the tidal study including WLEs, temperature, and specific conductance. Additionally, water quality data were obtained through laboratory analysis of groundwater samples taken on August 2 and 3, 2010.

3.3.4.1 Water Level Data

Table 3.3-1 lists summary statistics for the WLE data presented in **Appendix F**. Water levels at the surface water monitoring points (SWG-1, SWG-2, SWG-4, and SWG-5) varied during the tidal study over a range of 3.31 to 3.46 feet in response to twice daily high tide and low tide conditions. The lowest recorded level of -1.64 ft msl was recorded at SWG-2 and the highest recorded level was 1.96 ft msl at SWG-4. The values for station SWG-3 were not included in this summary because the station was not recording any data after thirteen hours into the study.

Water levels at the near shore groundwater monitoring wells (MW-2, MW-6, and MW-12) varied during the tidal study between a range of 0.92 to 2.19 feet in response to twice daily high tide and low tide conditions. Both the lowest and highest recorded levels in this group of wells was recorded at MW-2, with a low -0.82 and a high of 1.36 ft msl.

Water levels at the interior groundwater monitoring well locations (MW-10, MW-10D, MW-11, and MW-11D) varied over the tidal study over a range of 1.42 to 2.48 feet in response to twice daily high tide and low tide conditions. Even though the exact WLEs for MW-11 and MW-11D could not be derived, the range of water level variation could be estimated from the variation in the water column pressure head readings. The range of WLE fluctuation at the MW-10/MW-10D well pair were smaller (1.42 and 1.73 feet, respectively) when compared to those estimated for the MW-11/MW-11D well pair (2.31 to 2.48 feet, respectively). It is expected that the variation at the MW-11/MW-11D well pair would be greater than that MW-10/MW-10D well pair as the former is more seaward on a more narrow portion of the peninsula and therefore more directly affected by tidal cycles. The water level elevations at MW-10 varied between a minimum of 0.87 and a maximum of 2.29 ft msl and the water level elevation at MW-10D varied between a minimum of -0.28 and maximum of 1.45 ft msl.

Table 3.3-1

Summary of Tidal Study Data – Water Level Elevations

	Water Level Elevations				
Surface Water Stations	**Max (ft msl)**	**Date/Time**	**Min (ft msl)**	**Date/Time**	**Range (ft)**
SWG-1	1.76	7/16/10 1:38	-1.55	7/22/10 14:08	3.31
SWG-2	1.78	7/16/10 1:27	-1.64	7/29/10 7:27	3.42
SWG-3*	2.37	7/14/10 12:14	-0.11	7/14/10 19:44	2.48
SWG-4	1.96	7/16/10 1:25	-1.49	7/14/10 18:55	3.46
SWG-5	1.93	7/16/10 1:17	-1.46	7/29/10 7:47	3.38
Shoreline Wells					
MW-2	1.36	7/16/10 1:39	-0.82	7/24/10 15:39	2.19
MW-6	0.35	7/20/10 19:24	-0.57	7/29/10 19:24	0.92
MW-12	0.97	7/16/10 2:51	-0.16	7/29/10 19:21	1.13
Interior Wells					
MW-10	2.29	7/21/10 20:54	0.87	7/13/10 17:54	1.42
MW-10D	1.45	7/16/10 2:28	-0.28	7/29/10 18:58	1.73
	Total Pressure Head Readings (ft of water column)				
	Max (ft)	**Time**	**Min (ft)**	**Time**	**Range (ft)**
MW-11**	8.43	7/16/10 2:24	6.12	7/29/10 19:24	2.31
MW-11D**	21.41	7/16/10 2:19	18.93	7/29/10 19:19	2.48
	Magnitude of Mounding				
	Max (ft)	**Time**	**Min (ft)**	**Time**	**Range (ft)**
MW-10 to SWG-1	3.32	7/27/10 17:38	0.32	7/15/10 0:38	3.00
MW-10 to SWG-5	3.23	7/28/10 18:17	0.17	7/15/10 0:17	3.06

ft msl – feet relative to mean sea level.

Vertical Gradients

The vertical gradients of the groundwater flow field could be determined for the MW-10/MW-10D well pair throughout the tidal study. The screens in this well pair were separated by a distance of 25 feet. The vertical gradient data are summarized on **Table 3.3-2**. Measured vertical gradients were downward and relatively small with values ranging from 0.016 to 0.081. An example of the relationship between water levels in MW-10 and MW-10D over two tidal cycles is shown on **Figure 3.3-2**. This includes a graph of the water level fluctuation at surface water monitoring point SWG-1. As seen on the chart, the water levels in MW-10 and MW-10D were responding directly to tidal fluctuations in Indian River.

Table 3.3-2
Summary of Vertical Gradient Measurements

Vertical Gradients From Continuous Recorder Data								
	Difference in Water Level Elevations						**Gradient (over 25 ft)**	
Well Pairs	**Max (ft msl)**	**Date/Time**	**Min (ft msl)**	**Date/Time**	**Percent Downward**	**Percent Upward**	**Max**	**Min**
MW-10/MW-10D	2.02	7/29/10 7:24	0.40	7/13/10 23:54	100	0	0.081	0.016
Vertical Gradients From Beginning and End of Test Manual Measurements								
		Difference in Water Level Elevations						
	Well	**Date/Time**	**WLE (ft msl)**	**Difference (ft msl)**	**Direction of Gradient**	**Gradient (over 25 ft)**		
Beginning of Test	MW-10	7/13/10 13:34	1.39					
	MW-10 D	7/13/10 13:28	0.89	0.50	Down	0.020		
End of Test	MW-10	8/2/10 11:44	1.64					
	MW-10 D	8/2/10 11:38	0.30	1.34	Down	0.054		

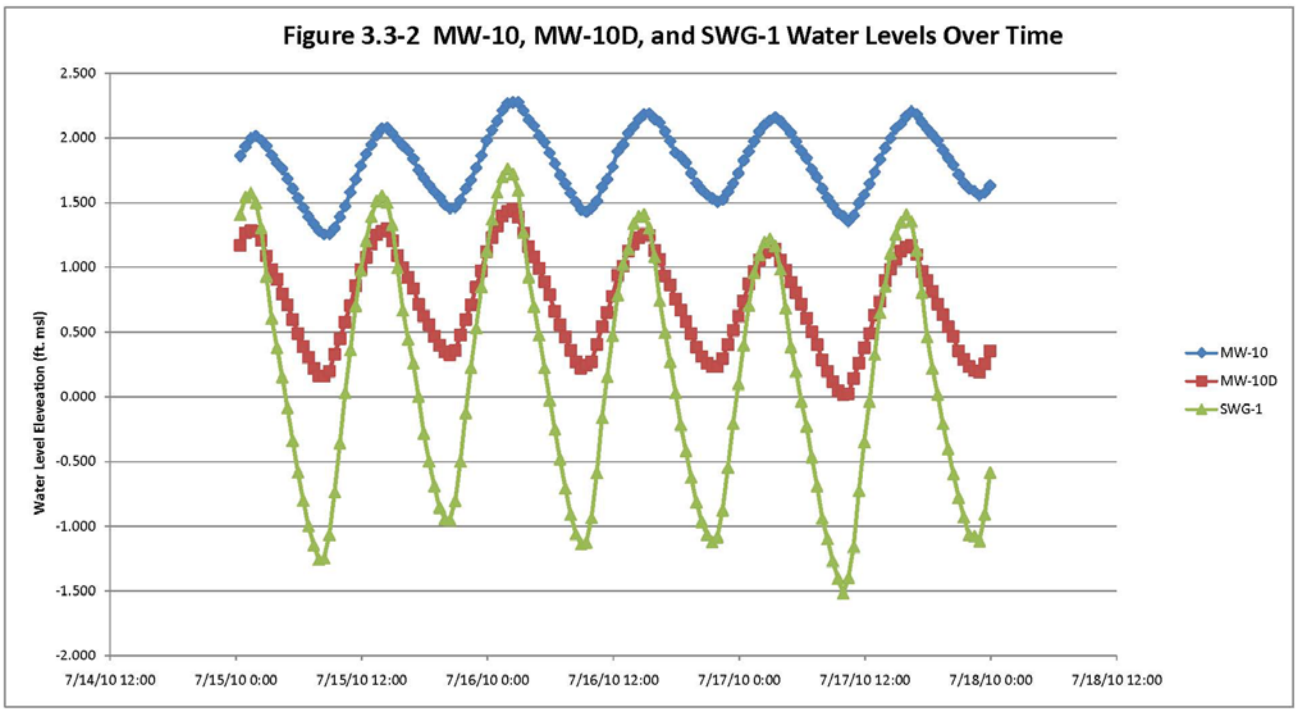


Figure 3.3-2 MW-10, MW-10D, and SWG-1 Water Levels Over Time

Horizontal Gradients

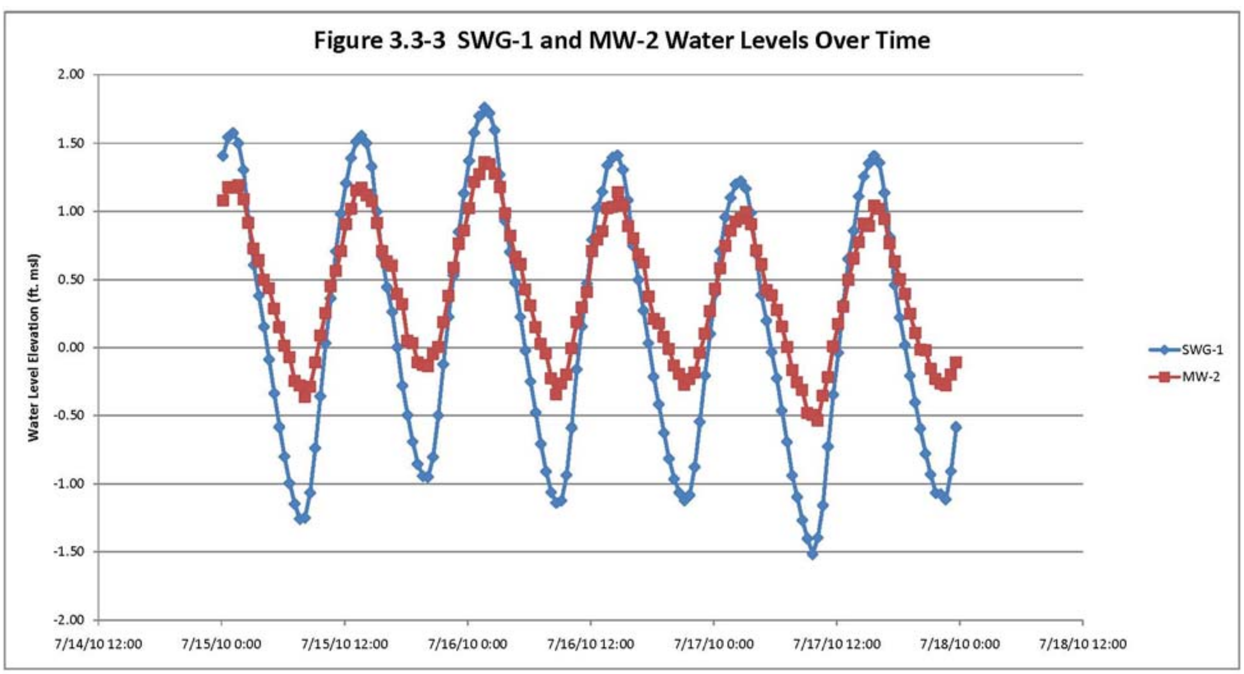
The WLE data were evaluated to determine the directions of horizontal groundwater gradients throughout the tidal study. Certain surface water monitoring stations were paired with near shore monitoring wells with the intent of comparing the water level elevations over time during the tidal study. These pairs included SWG-1/MW-2, SWG-2/MW-6, and SWG-5/MW-12. Over the course of the tidal study, the water levels varied at these pairs in response to tidal fluctuations within Indian River. When the water level elevation at the surface water monitoring point was higher than water level elevation in the monitoring well there was an inward gradient. That is, there was a potential for groundwater to move from the surface water body toward the Burton Island peninsula. When the water level elevation at the monitoring well was higher than the water level elevation in the surface water monitoring point there was outward gradient and a potential for groundwater to move from the peninsula toward Indian River or Island Creek. Comparisons of this nature were made for all of the data collected over the course of the 19-day tidal study. A summary of these comparisons is provided on **Table 3.3-3**. The horizontal gradients for the three monitoring point pairs were similar and indicate outward gradients were occurring between 51 to 68 percent of the time and inward gradients were occurring between 32 to 49 percent of the time during the tidal study, depending on position along the shoreline.

Table 3.3-3

Summary of Inward and Outward Gradients

Monitoring Point Pair	Percent Inward Gradient	Percent Outward Gradient
SWG-1/ MW-2	32.2	67.8
SWG-2/ MW-6	48.6	51.4
SWG-5/ MW-12	39.2	60.8

An example of the relationship between water levels in surface water monitoring points compared to near shore monitoring wells is shown in **Figure 3.3-3**. As seen in this figure, the water level in MW-2 responds directly to the water level in Indian River at SWG-1.



Examples of low tide, mid-tide, and high tide water level maps generated from the tidal study WLEs are shown on **Figures 3.3-4** through **3.3-6**. In the three depictions, there is subtle mounding of the water table in the central portion of the map causing groundwater flow to move outward toward the shoreline. In the depiction of the low tide and mid-tide water level maps, groundwater flow lines are shown continuing to the shorelines. This is the condition that occurred 51 to 68 percent of the time during the tidal study. In the depiction of the high tide water table, there is a reversal of these flow lines from outward to inward near the shorelines. This is the condition that occurred 32 to 49 percent of the time during the tidal study.

3.3.4.2 Specific Conductance Data

Specific conductance (SC) is a measure of the property of electrical conductance in a water sample and is directly correlated to the ionic activity of the sample. The ionic activity is a function of the concentration of dissolved minerals in the sample; therefore SC is commonly correlated with the measure of total dissolved solids in a sample; the higher the concentration of ionic (dissolved) constituents, the higher the SC.

Similar to the water level measurements, SC measurements were recorded at each monitoring station at ten minute intervals throughout the 19-day tidal study. In addition, SC measurements were collected during the groundwater sampling event on August 2 and 3, 2010. A summation of the SC data is shown on **Table 3.3-4**. The table lists maximum and minimum measurements and the time these measurements were taken during the tidal study. In general, there was little variability in the groundwater SC data. In general, the SC values collected during the sampling event were slightly higher but similar to the range of values recorded during the tidal study. Exceptions occurred in the data collected for MW-11D where the maximum of the range for the tidal study was 3,771 microSiemens per centimeter (µS/cm) and the value recorded during the sampling event was 11,290 µS/cm. **Table 3.3-4** also lists the percent of time during the tidal study when SC values fell into various total dissolved solids categories. TDS was estimated assuming that SC in (µS/cm) x 0.5 equals TDS in mg/L. Some apparent relationships were observed when examining the data in this manner. Greater than 92 percent of the time, the surface water was characteristic of a saline water (estimated TDS between 15,000 and 30,000 mg/L). The TDS estimated for the 14 monitoring wells was generally much lower. The water in MW-2 remained brackish (in the range from 1,000 to 5,000 mg/L estimated TDS) for the entire tidal study. The water in MW-6 remained fresh (less than 1,000 mg/L TDS) for the entire tidal study and the water in MW-12 remained just inside the lower limit of the highly brackish category (range from 5,000 to 15,000 mg/L estimated TDS) for the entire tidal study. At the monitoring well pair MW-10/MW-10D the shallow groundwater was brackish and the deeper

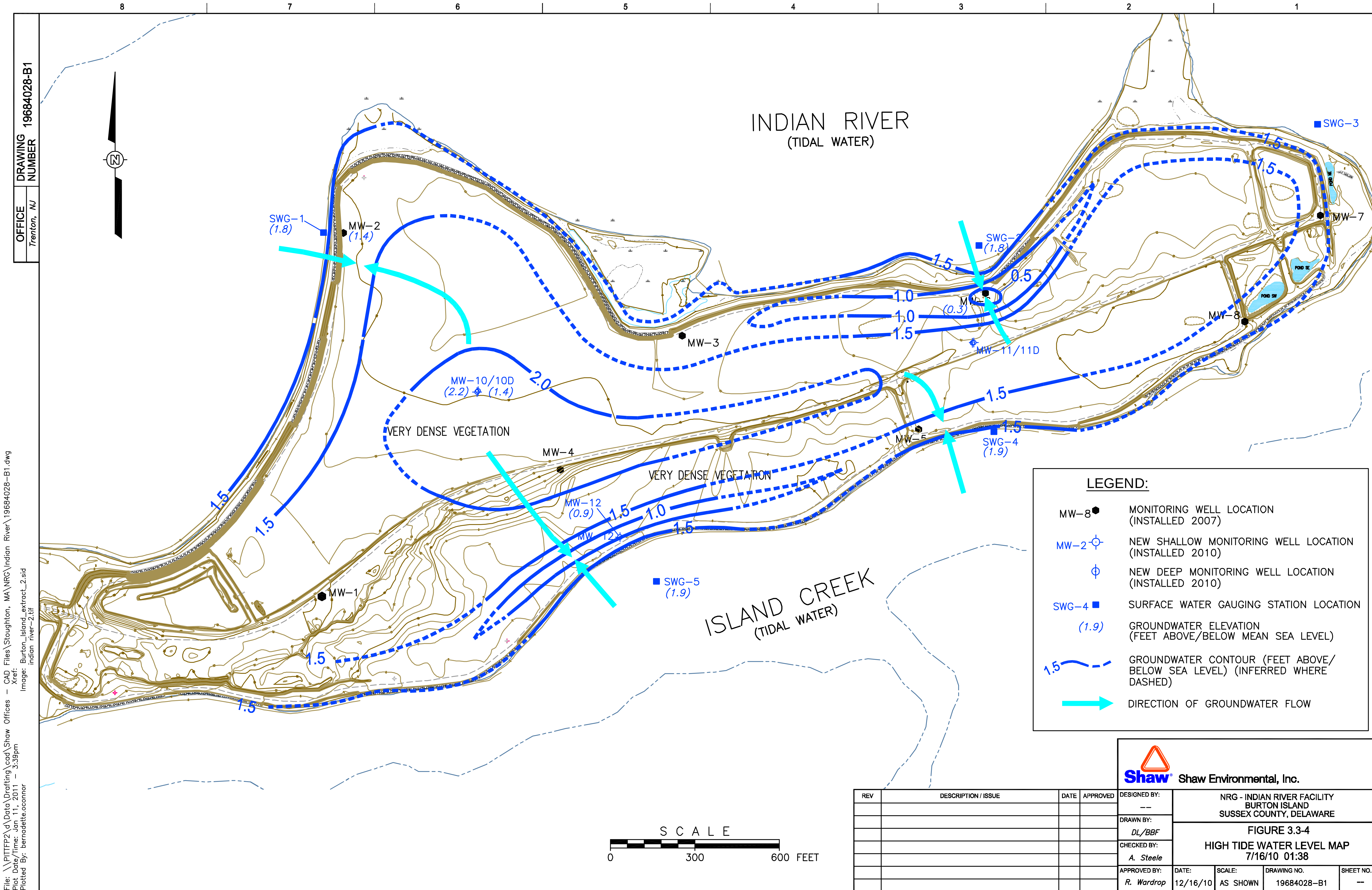


FIGURE 3.3-4
HIGH TIDE WATER LEVEL MAP
7/16/10 01:38

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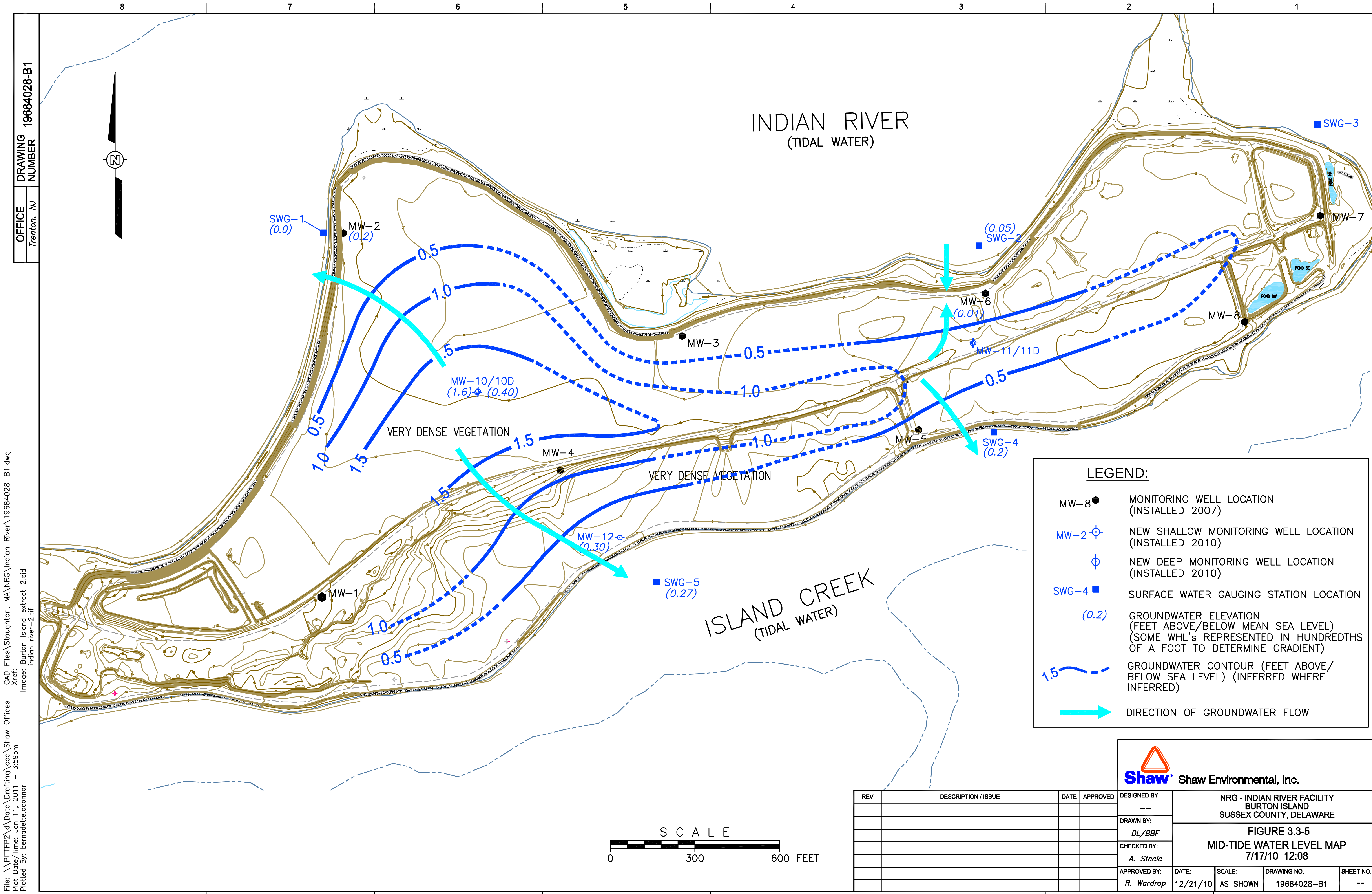

8 7 6 5 4 3 2 1
OFFICE
Trenton, NJ
DRAWING NUMBER
19684028-B1
N
INDIAN RIVER
(TIDAL WATER)
ISLAND CREEK
(TIDAL WATER)
SWG-1
(0.0)
MW-2
(0.2)
SWG-2
(0.05)
SWG-3
MW-3
MW-6
(0.01)
MW-7
MW-8
MW-11/11D
MW-10/10D
(1.6)
(0.40)
MW-4
MW-5
SWG-4
(0.2)
MW-1
MW-12
(0.30)
SWG-5
(0.27)
VERY DENSE VEGETATION
VERY DENSE VEGETATION
POND SE
POND SW
0.5
1.0
1.5
LEGEND:
MW-8 MONITORING WELL LOCATION (INSTALLED 2007)
MW-2 NEW SHALLOW MONITORING WELL LOCATION (INSTALLED 2010)
NEW DEEP MONITORING WELL LOCATION (INSTALLED 2010)
SWG-4 SURFACE WATER GAUGING STATION LOCATION
(0.2) GROUNDWATER ELEVATION (FEET ABOVE/BELOW MEAN SEA LEVEL) (SOME WHL's REPRESENTED IN HUNDREDTHS OF A FOOT TO DETERMINE GRADIENT)
1.5 GROUNDWATER CONTOUR (FEET ABOVE/ BELOW SEA LEVEL) (INFERRED WHERE INFERRED)
DIRECTION OF GROUNDWATER FLOW
SCALE
0 300 600 FEET
File: \\PITFP2\d\Data\Drafting\cad\Shaw Offices - CAD Files\Stoughton, MA\NRG\Indian River\19684028-B1.dwg
Xref:
Image: Burton_Island_extract_2.sid
indian river-2.tif
Plot Date/Time: Jan 11, 2011 - 3:59pm
Plotted By: bernadette.oconnor
Shaw Shaw Environmental, Inc.
REV | DESCRIPTION / ISSUE | DATE | APPROVED
DESIGNED BY: --
DRAWN BY: DL/BBF
CHECKED BY: A. Steele
APPROVED BY: R. Wardrop
NRG - INDIAN RIVER FACILITY
BURTON ISLAND
SUSSEX COUNTY, DELAWARE
FIGURE 3.3-5
MID-TIDE WATER LEVEL MAP
7/17/10 12:08
DATE: 12/21/10
SCALE: AS SHOWN
DRAWING NO. 19684028-B1
SHEET NO. --

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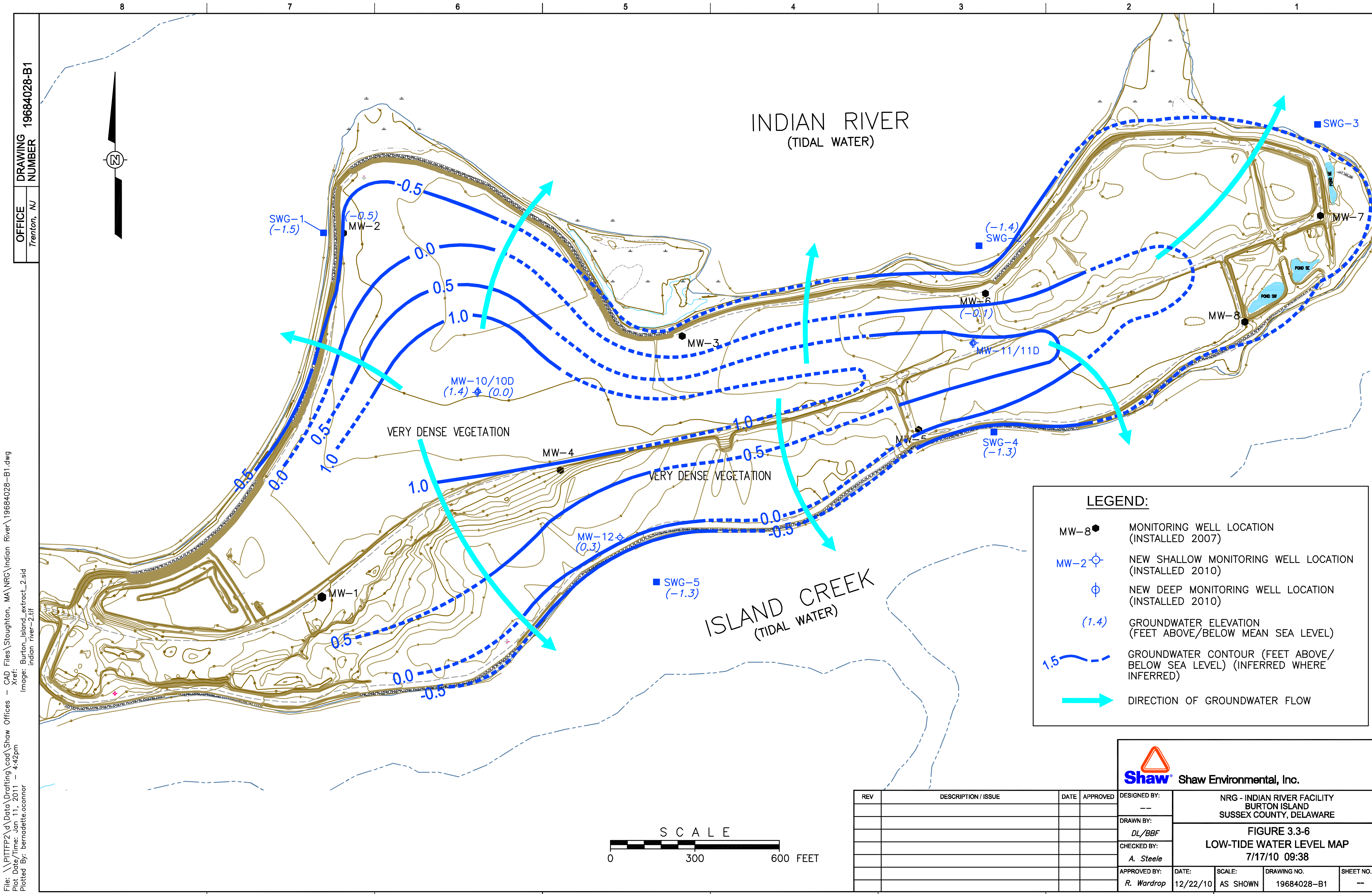

INDIAN RIVER
(TIDAL WATER)
ISLAND CREEK
(TIDAL WATER)
VERY DENSE VEGETATION
VERY DENSE VEGETATION
SWG-1
(-1.5)
SWG-2
(-1.4)
SWG-3
SWG-4
(-1.3)
SWG-5
(-1.3)
MW-1
MW-2
(-0.5)
MW-3
MW-4
MW-5
MW-6
(-0.1)
MW-7
MW-8
MW-10/10D
(1.4)
(0.0)
MW-11/11D
MW-12
(0.3)
-0.5
0.0
0.5
1.0
LEGEND:
MW-8 MONITORING WELL LOCATION (INSTALLED 2007)
MW-2 NEW SHALLOW MONITORING WELL LOCATION (INSTALLED 2010)
NEW DEEP MONITORING WELL LOCATION (INSTALLED 2010)
(1.4) GROUNDWATER ELEVATION (FEET ABOVE/BELOW MEAN SEA LEVEL)
1.5 GROUNDWATER CONTOUR (FEET ABOVE/ BELOW SEA LEVEL) (INFERRED WHERE INFERRED)
DIRECTION OF GROUNDWATER FLOW
SCALE
0 300 600 FEET
OFFICE Trenton, NJ
DRAWING NUMBER 19684028-B1
Shaw Environmental, Inc.
REV
DESCRIPTION / ISSUE
DATE
APPROVED
DESIGNED BY: --
DRAWN BY: DL/BBF
CHECKED BY: A. Steele
APPROVED BY: R. Wardrop
NRG - INDIAN RIVER FACILITY
BURTON ISLAND
SUSSEX COUNTY, DELAWARE
FIGURE 3.3-6
LOW-TIDE WATER LEVEL MAP
7/17/10 09:38
DATE: 12/22/10
SCALE: AS SHOWN
DRAWING NO. 19684028-B1
SHEET NO. --
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Plot Date/Time: Jan 11, 2011 - 4:42pm
Plotted By: bernadette.oconnor
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indian river-2.tif

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Table 3.3-4

Summary of Tidal Study Specific Conductance Data

	Specific Conductance at Time of Sampling (in uS/cm)	Specific Conductance During Tidal Study (in uS/cm) Max	Date/Time	Min	Date/Time	% of Time in Fresh Water Range *	% of Time in Brackish Range*	% of Time in Highly Brackish Range*	% of Time in Saline Range*
Shoreline Wells									
MW 2	2393	2347	7/20/10 15:39	2027	7/26/10 12:09	0.00%	100.00%	0.00%	0.00%
MW 6	974	824	7/15/10 12:54	792	7/14/10 0:54	100.00%	0.00%	0.00%	0.00%
MW 12	16380	12235	7/29/10 21:21	11845	7/14/10 21:21	0.00%	0.00%	100.00%	0.00%
MW 3	1871	--	--	--	--	--	--	--	--
MW 5	1209	--	--	--	--	--	--	--	--
MW 7	603	--	--	--	--	--	--	--	--
MW 8	1332	--	--	--	--	--	--	--	--
Interior Wells									
MW 10	3226	3549	7/13/10 23:24	3099	7/25/10 16:24	0.00%	100.00%	0.00%	0.00%
MW 10D	1635	1069	7/13/10 17:58	760	7/29/10 21:58	100.00%	0.00%	0.00%	0.00%
MW 11	1056	872	7/31/10 16:54	669	7/13/10 20:24	100.00%	0.00%	0.00%	0.00%
MW 11D	11290	3771	7/16/10 2:19	3744	7/13/10 18:49	0.00%	100.00%	0.00%	0.00%
MW 1	394	--	--	--	--	--	--	--	--
MW 4	187	--	--	--	--	--	--	--	--
Background Well									
MW 9	85	--	--	--	--	--	--	--	--
Surface Water Stations									
SWG 1	--	48800	7/25/10 15:08	136	7/14/10 19:38	5.59%	0.77%	0.88%	92.76%
SWG 2	--	44867	7/24/10 14:27	1464	7/29/10 7:27	0.11%	0.00%	0.22%	99.67%
SWG 3**	--	44203	7/14/10 13:44	64	7/14/10 19:14	18.52%	0.00%	0.00%	81.48%
SWG 4	--	51360	7/24/10 21:55	67	7/14/10 19:25	4.84%	0.00%	0.22%	94.95%
SWG 5	--	48869	7/25/10 13:17	451	7/29/10 7:17	0.33%	0.00%	0.33%	99.34%

NOTES:

*Classification	TDS (in mg/L)	SC (in uS/cm)
Fresh	<1,000	<2,000
Brackish	1,000 - 5,000	2,000 - 10,000
Highly Brackish	5,000 - 15,000	10,000 - 30,000
Saline	15,000 - 30,000	30,000 - 60,000
Sea Water	30,000 - 40,000	60,000 - 80,000

Assuming total dissolved solids (TDS) in mg/L is 0.5 times specific conductance (SC) in uS/cm.
**the SG-3 data set is limited as the continuous logger malfunctioned 13 hours into the nineteen day test.
mg/L - milligrams per Liter
uS/cm - micro-Siemens per centimeter.

groundwater was fresh (less dense) 100 percent of the time. This relationship was reversed at the MW-11/MW-11D well pair where the shallow groundwater was estimated to be fresh and the deeper groundwater was brackish 100 percent of the time. If the value recorded during the sampling event is used, the deeper water at MW-11D would be categorized as highly brackish. The variation in estimated TDS with depth between the two well pairs could be attributed to well screen positions and the position of saline water from the surrounding surface water bodies intruding into less dense groundwater under Burton Island.

The relatively persistent saline character (elevated TDS) in the surface water bodies surrounding Burton Island is documented in the Indian River Power Plant 316(a) study report (Entrix, 2000). As stated in the study report, the permanent opening of the Indian River Bay inlet by 1940 and dredging of a channel from the inlet to Millsboro Dam in 1951 increased the magnitude of marine water intrusion into the bay. This intrusion of marine water or tidal flushing increased 5-fold in volume over the 50 year plus period from 1940 to the 1990s due to ongoing scouring of the inlet. The increase in tidal flushing has resulted in significant changes in the salinity regime in the estuary. For example, in the late 1960s and early 1970s, the mean salinity adjacent to the facility intake was approximately 7,000 mg/L (Jensen, 1974). By 1990, the mean salinity at IRPP was approximately 19,000 mg/L (Ullman, et al., 1993). At the time of the 316(a) study (1998 / 1999), the lower Indian River estuary had salinity values ranging between 25,000 and 30,000 mg/L and the middle estuary had a salinity of 18,000 to 25,000 mg/L. These values are consistent with the specific conductance measurements taken at the surface water monitoring stations over 92 percent of the time during the tidal study.

Based on the SC measurements taken during the tidal study and data reported in the 316(a) study report, the groundwater within Burton Island is fresh to brackish in quality and it is surrounded by saline surface water bodies. Fresh water influxes from the inland portion of the Columbia Formation aquifer during low tide conditions do not have a significant effect on the total dissolved mineral content of surface water, which is saline most of the time. A small percentage of the time (less than 8% of the time) during the tidal study, the estimated SC at the surface water monitoring stations dropped below the saline water range. This occurred at the lowest tides, during 18 of the 37 low tides monitored at SWG-1, during 3 of the low tides monitored at SWG-2, during 15 of the low tides monitored at SWG-4, and during 5 of the low tides monitored at SWG-5. The higher number of times when SC dropped below the saline water range occurred at the surface water monitoring stations that were installed closest to the shoreline of Burton Island (at SWG-1 and SWG-4). An example of how the SC of surface water changed at the lowest of low tide conditions is shown on the graph in **Figure 3.3-7**. This figure illustrates a pattern of

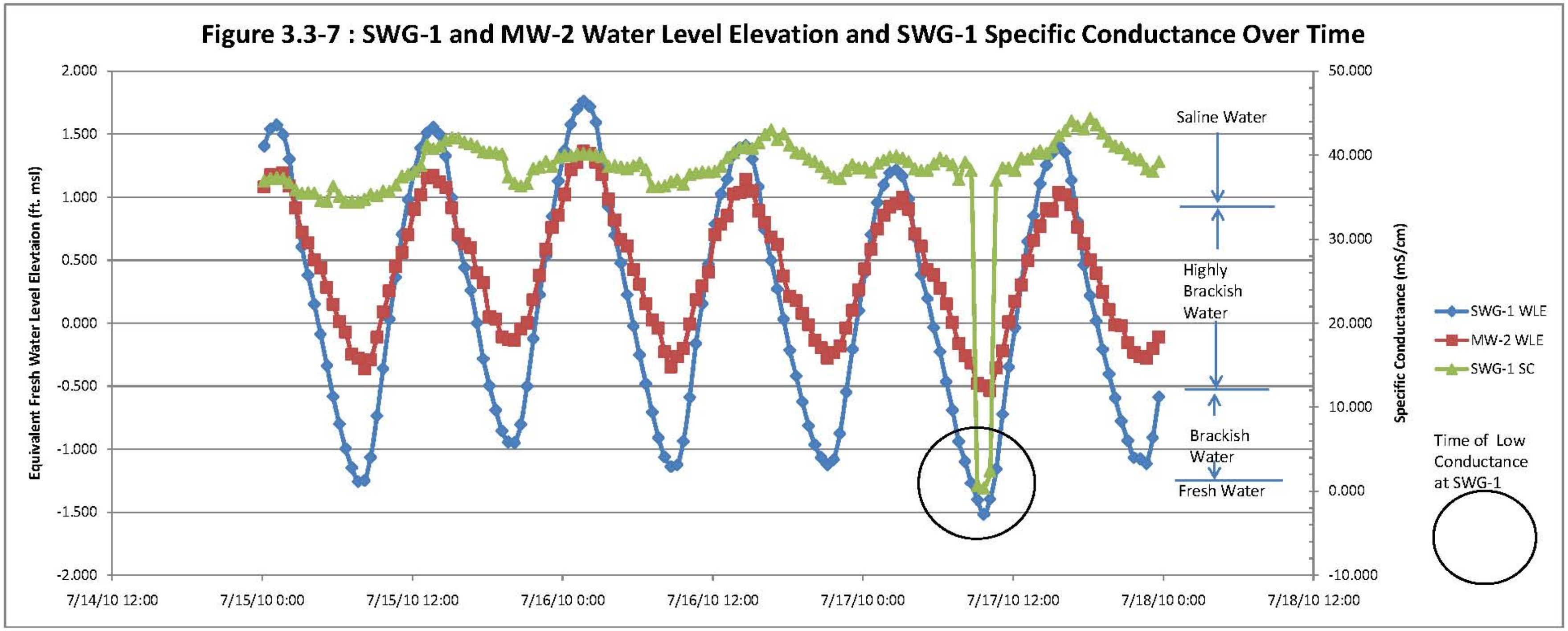
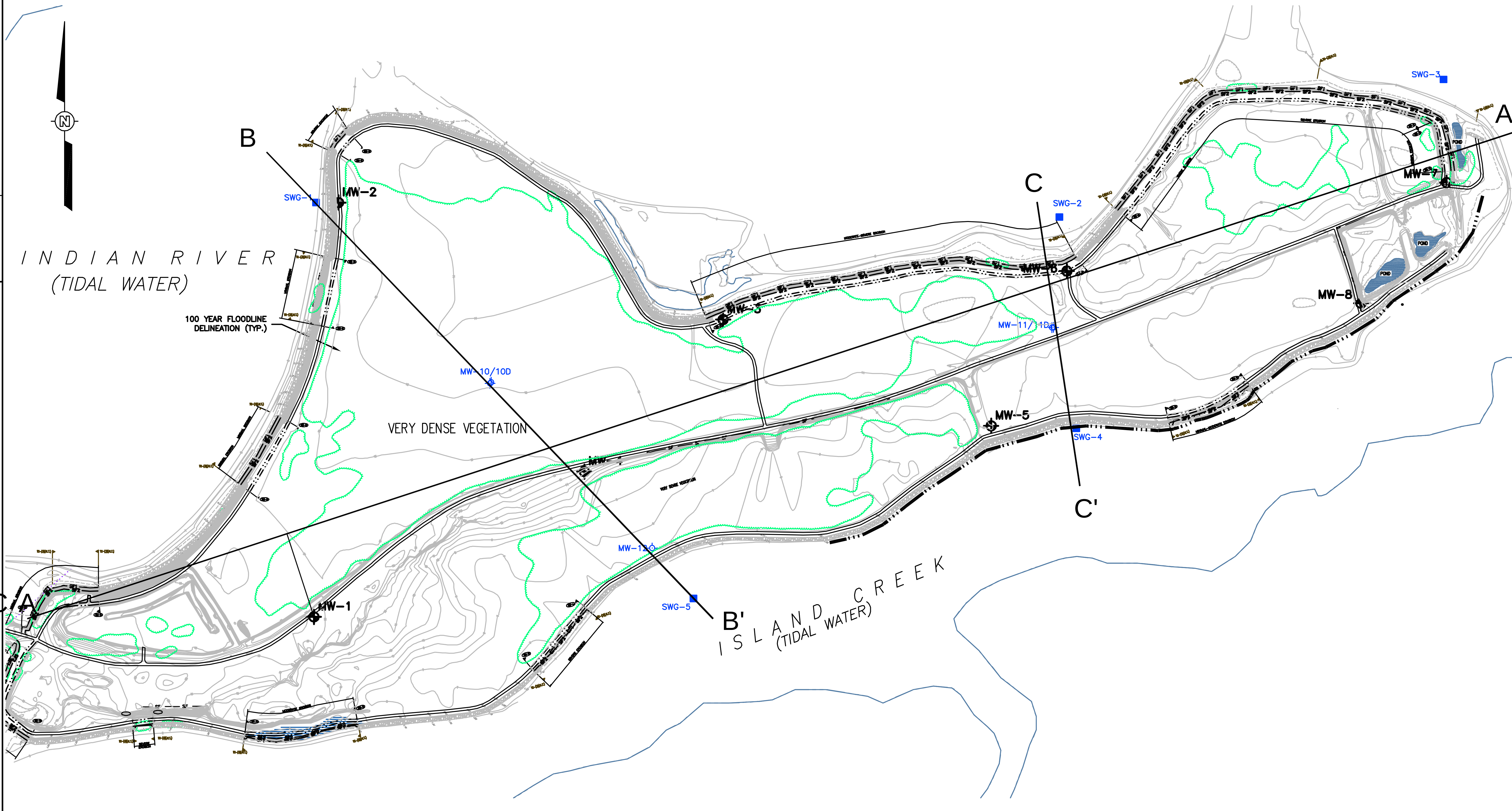


Figure 3.3-7 : SWG-1 and MW-2 Water Level Elevation and SWG-1 Specific Conductance Over Time
Equivalent Fresh Water Level Elevtaion (ft. msl)
Specific Conductance (mS/cm)
2.000
1.500
1.000
0.500
0.000
-0.500
-1.000
-1.500
-2.000
50.000
40.000
30.000
20.000
10.000
0.000
-10.000
7/14/10 12:00
7/15/10 0:00
7/15/10 12:00
7/16/10 0:00
7/16/10 12:00
7/17/10 0:00
7/17/10 12:00
7/18/10 0:00
7/18/10 12:00
Saline Water
Highly Brackish Water
Brackish Water
Fresh Water
SWG-1 WLE
MW-2 WLE
SWG-1 SC
Time of Low Conductance at SWG-1

water level elevation relationships during every low tide condition when the water level in monitoring well MW-2 is higher than the water level in surface water monitoring SWG-1 and an outward flow gradient is indicated. During the low tide on July 17, 2010 at 9:38 AM, the difference in water level elevations was greatest and a dramatic change in specific conductance at SWG-1 from saline water to lower brackish water values is seen. As shown on **Table 3.3-4**, this condition was present less than 8% of the time during the tidal study. The observation of large decreases in surface water SC during those low tide times when the surface water elevation is lowest is one of the most important findings of the tidal study as these are indicative of when mass loading is occurring to the surface water bodies surrounding Burton Island. Further discussion of mass loading is provided in Section 3.3.6.

The distribution of SC values with depth were examined using a series of three cross sections across Burton Island. The lines of cross section are shown on **Figure 3.3-8** and the cross sections are shown on **Figure 3.3-9** (Sections A-A', running west to east along the long axis of the peninsula) and **Figure 3.3-10** (Sections Sections B-B' and C-C', running north to south across the peninsula). The cross-sections were produced using SC values from the high tide condition occurring at approximately 01:25 on September 16, 2010. As depicted on **Figure 3.3-9**, less dense shallow groundwater under Burton Island sits above more dense groundwater affected by saline water intrusion moving under the peninsula from the east (seaward). This interpretation is based on the SC value at MW-11D of 3765 µS/cm and the elevated SC values recorded for Indian River and Island Creek. If the SC value for MW-11D recorded at the time of sampling (11,900 µS/cm) were used then the 10,000 µS/cm contour would be drawn closer to the surface. Also, note the shallow zone of elevated SC surrounding well MW-10 which is interpreted to be a zone of where ash leachate causes groundwater to become more mineralized.

Figure 3.3-10 shows north-south Section B-B' running across Burton Island through the MW-10/MW-10D well pair and north-south Section C-C' running across Burton Island through the MW-11 / MW-11D well pair. Similar to **Figure 3.3-9**, Section B-B' depicts less dense shallow groundwater under Burton Island above more dense groundwater affected by saline water intrusion. This interpretation is based on the higher SC value at MW-12 of 12,173 µS/cm and the elevated SC values recorded for Indian River and Island Creek (greater than 40,000 µS/cm). Note the envelope of higher SC water is pushed north towards the interior of the peninsula based on the SC value for MW-12. Like Section A-A' (**Figure 3.3-9**) the shallow zone of elevated SC surrounds well MW-10.



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LEGEND:

A———A'	LINE OF CROSS SECTION
	TREE BOUNDARY LINE
MW-2	NEW SHALLOW MONITORING WELL AND ID
	NEW DEEP MONITORING WELL
	SURFACE WATER GAUGE STATION
MW2	MONITORING WELL LOCATION

SCALE

0 300 600 FEET

REV	DESCRIPTION / ISSUE	DATE	APPROVED
1	UPDATED SHORLINE STABILIZATION FOOTPRINT	9/08/10	G. Lavorgna
2	UPDATED MW AND SW GAUGE STATION LOCATIONS	9/08/10	G. Lavorgna

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DESIGNED BY: --	NRG - INDIAN RIVER FACILITY BURTON ISLAND SUSSEX COUNTY, DELAWARE
DRAWN BY: A.Y./BBF	FIGURE 3.3-8 LINES OF CROSS SECTION
CHECKED BY: A. Steele	
APPROVED BY: R. Wardrop	DATE: 9/08/10 — SCALE: AS SHOWN — DRAWING NO. 19684010-B6 — SHEET NO. --

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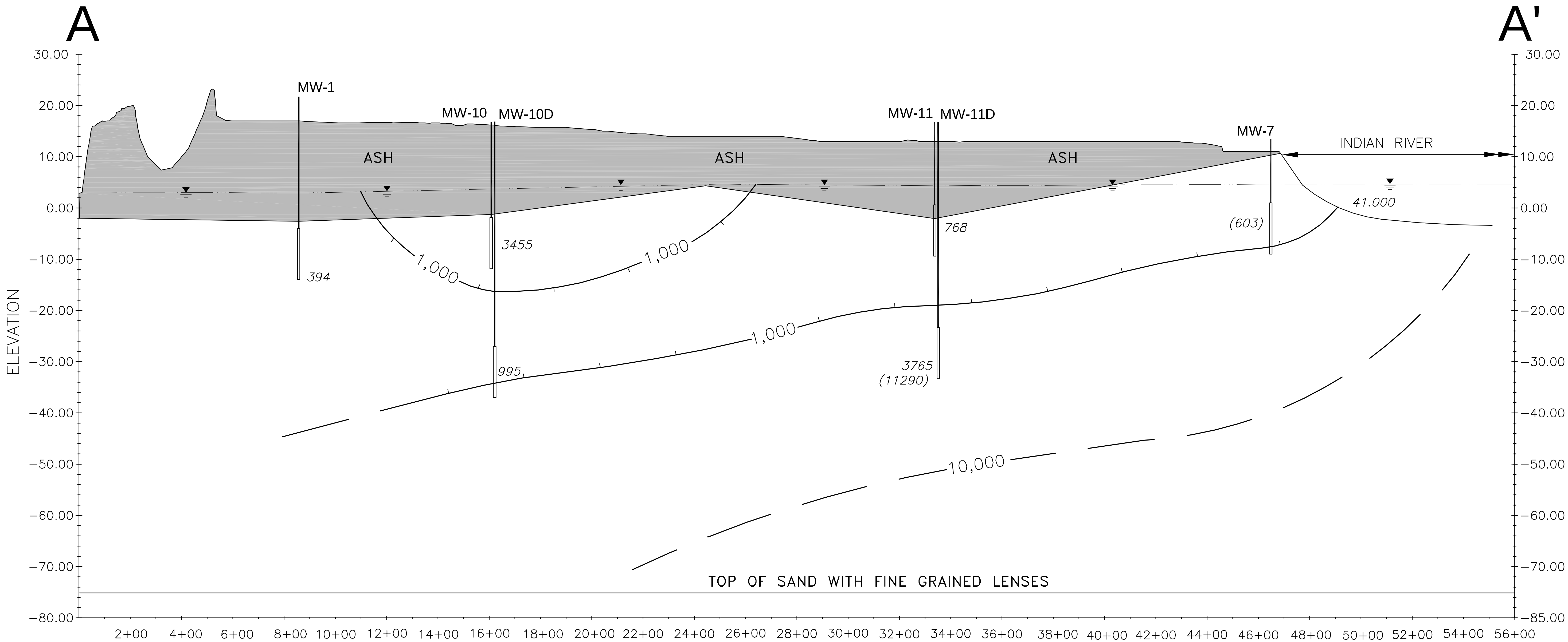

CROSS-SECTION A-A'

VERTICAL SCALE

0 20 40 FEET

HORIZONTAL SCALE

0 400 800 FEET

LEGEND:

MONITORING WELL

SCREENED INTERVAL
345 SPEC. COND (in uS/cm)

—1,000— SPECIFIC CONDUCTANCE CONTOUR (LOGARITHMIC CONTOUR INTERVAL)

WATER TABLE

(1,290) VALUE AT TIME OF SAMPLING

Shaw® Shaw Environmental & Infrastructure, Inc.

REV	DESCRIPTION / ISSUE	DATE	APPROVED

DESIGNED BY: --	NRG - INDIAN RIVER FACILITY BURTON ISLAND SUSSEX COUNTY, DELAWARE
DRAWN BY: AY/BBF	FIGURE 3.3-9 CROSS-SECTION A-A' SPECIFIC CONDUCTANCE AT HIGH TIDE 7/16/10 01:25
CHECKED BY: R. Wardrop	
APPROVED BY: R. Wardrop	DATE: 11/29/10 · SCALE: AS SHOWN · DRAWING NO. 19684010-B6 · SHEET NO. --

OFFICE Trenton, NJ

DRAWING NUMBER 19684010-B6

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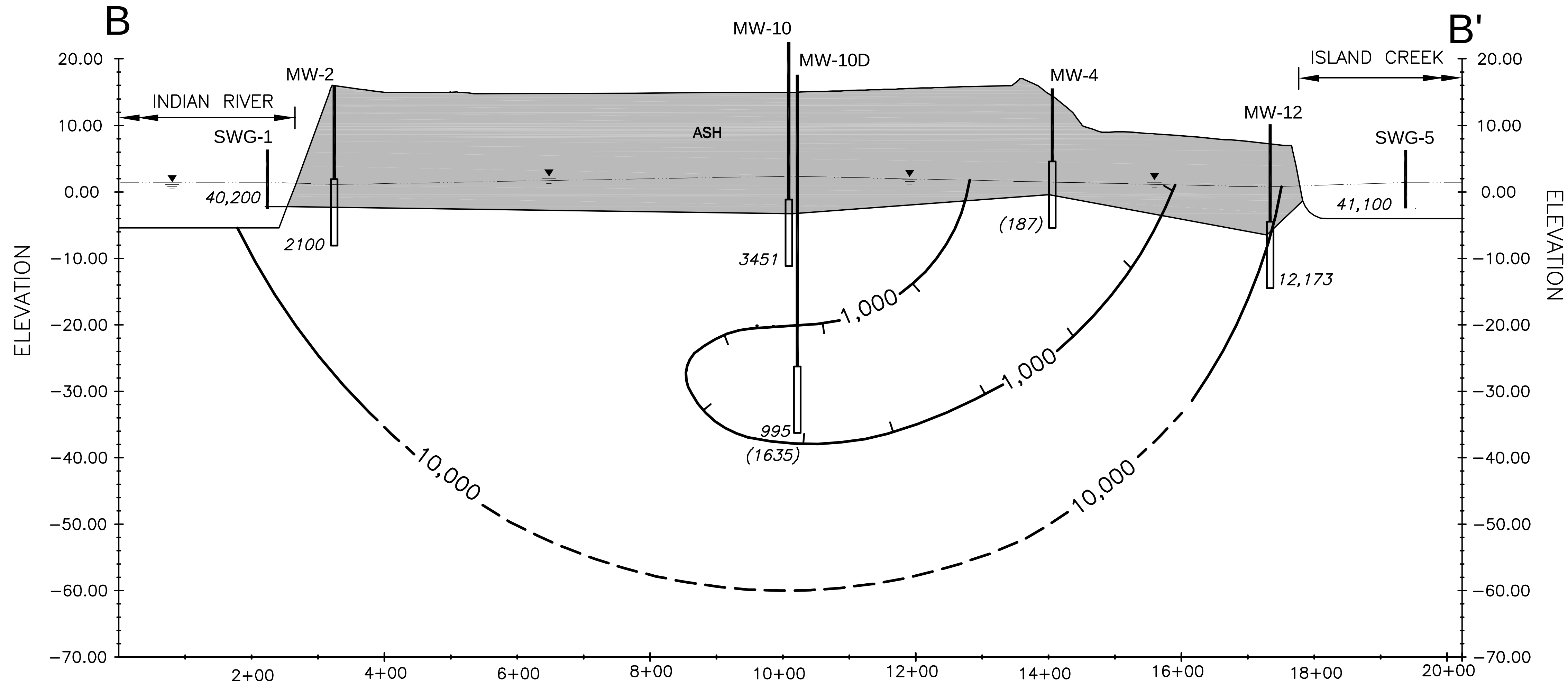
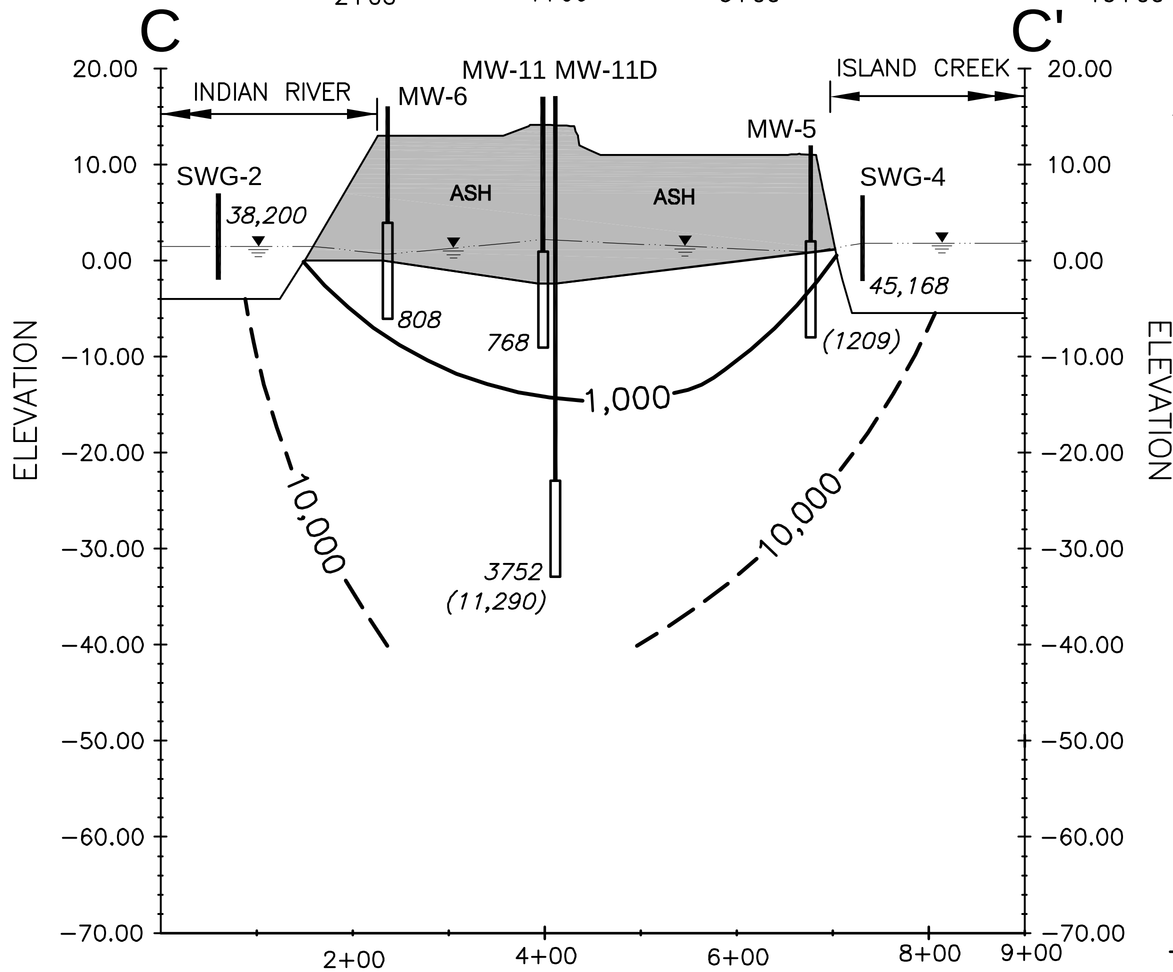


CROSS-SECTION B-B'



CROSS-SECTION C-C'

LEGEND:

MONITORING WELL

← SCREENED INTERVAL
345 SPEC. COND (in uS/cm)

—1,000— SPECIFIC CONDUCTANCE CONTOUR (LOGARITHMIC CONTOUR INTERVAL)

▽ WATER TABLE

(1635) VALUE AT TIME OF SAMPLING

VERTICAL SCALE
0 20 40 FEET

HORIZONTAL SCALE
0 200 400 FEET

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REV	DESCRIPTION / ISSUE	DATE	APPROVED
1	UPDATED SHORLINE STABILIZATION FOOTPRINT	9/08/10	G. Lavorgna
2	UPDATED MW AND SW GAUGE STATION LOCATIONS	9/08/10	G. Lavorgna

DESIGNED BY: --
DRAWN BY: A.Y.
CHECKED BY: A. Steele
APPROVED BY: R. Wardrop

NRG - INDIAN RIVER FACILITY
BURTON ISLAND
SUSSEX COUNTY, DELAWARE

FIGURE 3.3-10
SPECIFIC CONDUCTANCE CROSS-SECTIONS
B-B' AND C-C' AT HIGH TIDE
7/16/10 01:25

DATE: 9/08/10 | SCALE: AS SHOWN | DRAWING NO. 19684010-B6 | SHEET NO. --

OFFICE Trenton, NJ
DRAWING NUMBER 19684010-B6

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Plot Date/Time: Jan 26, 2011 - 5:44pm
Plotted By: bernadette.oconnor

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Section C-C’ runs across Burton Island through the MW-11/MW-11D well pair. Similar to Sections A-A’ and B-B’, Section C-C’ depicts less dense shallow groundwater under Burton Island above more dense groundwater affected by saline water intrusion. This interpretation is based on the higher SC value at MW-11D, Indian River and Island Creek. Note again that the 10,000 µS/cm contour would be pushed higher if the SC value for MW-11D recorded at the time of sampling (11,900 µS/cm) were used to create the section.

3.3.4.3 Water Quality Data

As part of the RI, groundwater samples were collected for laboratory analysis on August 2 and August 3, 2010. These samples were sent to Test America Laboratories in Edison, New Jersey and analyzed for TAL metals and cyanide. In addition, at the request of DNREC-SIRB, select groundwater samples were analyzed for uranium and thorium. The metals and major ions were sampled and analyzed for both total and dissolved fractions. The dissolved values were used to estimate the mass loading of COIs to the surrounding surface water bodies which is described in Section 3.3.6. A summary of the analytical results and the laboratory report for groundwater samples are provided in **Appendix G**.

Dissolved fraction results for which detections occurred in monitoring wells are listed on **Table 3.3-5**. These data were screened using background concentrations detected in the sample from MW-9 and DNREC’s URS criteria for surface water. The results of this screening are summarized on **Table 3.3-5**. Based on the frequency of detections, above background and above URSs, arsenic, barium, iron, and manganese were carried forward for mass loading assessment. **Table 3.3-6** shows a listing of the concentrations for these parameters by monitoring well type and position on Burton Island (interior wells and wells located along the shoreline).

Table 3.3-5

Screening of Dissolved TAL Metal Analytical Results

	URS for Protection of Environment Surface Water (mg/L)	URS for Protection of Human Health Groundwater (mg/L)	Background MW-9 (mg/L)		Summary of Results for 13 Downgradient Monitoring Wells: Number of Detections Greater Than Background	Number of Detections Greater Than Surface Water URS	Range of Detections: Min (mg/L)	Max (mg/L)
METALS								
Aluminum ,Dissolved	0.087	0.2	0.152		1	2	0.0402 U	2.22
Antimony ,Dissolved	0.03	0.005	0.0018	U	2	0	0.0018 U	0.0043
Arsenic ,Dissolved	0.003	0.050/0.0005 (a)	0.0018	U	13	11	0.0026	3.43
Barium ,Dissolved	0.004	2.0/0.26 (a)	0.042		6	13	0.0158	0.697
Beryllium ,Dissolved	0.0007	0.004	0.00085	U	NA	NA	0.00085 U	0.00085 U
Cadmium ,Dissolved	0.001	0.005	0.0021	U	NA	NA	0.0021 U	0.0021 U
Chromium ,Dissolved	0.011	0.011/0.035 (b)	0.0041	U	1	1	0.0041 U	0.0155
Cobalt ,Dissolved	0.023	0.22	0.0038	U	3	0	0.0038 U	0.023
Copper ,Dissolved	0.012	1.3	0.0048	J	8	2	0.004 U	0.0132
Iron ,Dissolved	1	0.3	0.122	U	13	11	0.221	56.2
Lead ,Dissolved	0.003	0.015	0.0011	U	1	0	0.0011 U	0.0013
Manganese ,Dissolved	0.08	0.05	0.0138		13	11	0.0428	2.08
Mercury ,Dissolved	0.001	0.002	0.00018	U	NA	NA	0.00018 U	0.00018 U
Nickel ,Dissolved	0.16	0.1	0.0035	U	3	0	0.0035 U	0.0534
Selenium ,Dissolved	0.0004	0.5	0.0024	U	2	13	0.0024 U	0.0166
Silver ,Dissolved	0.0004	0.1	0.004	U	NA	NA	0.004 U	0.004 U
Thallium ,Dissolved	0.009	0.002	0.00075	U	3	1	0.00075 U	0.0107
Vanadium ,Dissolved	0.19	0.026	0.004	J	8	1	0.0035 U	0.101
Zinc ,Dissolved	0.11	2	0.077		1	0	0.0153 U	0.0913
MAJOR CATIONS								
Calcium ,Dissolved	NDA	NDA	3.18		13	0	26.2	146
Magnesium ,Dissolved	NDA	NDA	2		13	0	9.9	404
Potassium ,Dissolved	NDA	NDA	1.73		13	0	12.3	110
Sodium ,Dissolved	NDA	NDA	6.55		13	0	7.03	3000

J: Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

U: Indicates the analyte was analyzed for but not detected.

NDA - No data available (per DNREC HSCA Guidance, dated December 1999)

(a) Some analytes have two groundwater URS values presented (eg. 2/1): lowest value to be used for screening purposes

(b) Standards listed for Chromium VI and compounds (Chromium III and compounds stds: 0.1/12.0)

Table 3.3-6

COI Dissolved Metal Concentrations Organized by Monitoring Well Position

		Background Well	Interior Monitoring Wells						Near Shore Monitoring Wells						
Parameter		**MW-9**	**MW-1**	**MW-4**	**MW-10**	**MW-10D**	**MW-11**	**MW-11D**	**MW-2**	**MW-3**	**MW-5**	**MW-6**	**MW-7**	**MW-8**	**MW-12**
Arsenic ,Dissolved	mg/L	<0.0018	0.453	0.142	3.43	0.0029	0.658	0.173	0.211	0.0352	0.0634	0.15	0.701	0.547	0.0026
Barium ,Dissolved	mg/L	0.042	0.375	0.321	0.337	0.0397	0.0249	0.297	0.0158	0.0351	0.0396	0.0439	0.0209	0.0269	0.697
Iron ,Dissolved	mg/L	<0.122	44.9	1.27	9.66	6.65	31.2	56.2	11.5	0.221	2.95	24.5	25.5	10.6	0.451
Manganese ,Dissolved	mg/L	0.0138	2.08	0.196	0.315	0.122	0.395	0.474	0.23	0.0428	0.0773	0.524	0.217	0.129	0.208

Field Paramenters

pH	std. units	5.06	6.56	6.16	6.23	6.59	6.35	6.47	6.47	6.58	6.02	6.71	6.47	6.52	5.43
Temperature	C	18.48	24.06	17.06	16.06	15.66	16.75	15.70	18.57	16.72	16.71	19.14	16.86	16.21	17.94
Specific Cond	uS/cm	85	394	187	3226	1635	1056	11290	2393	1871	1209	974	603	1332	16380
ORP	mV	226.7	-88.3	75.0	-87.9	-78.8	-85.3	-130.8	-38.5	-0.5	22.8	-65.9	72.5	-56.3	-399.0
DO	mg/L	7.12	7.46	3.92	0.71	0.08	0.16	0.35	6.16	5.30	4.04	7.39	4.75	3.51	0.35
Turbidity	NTU	54.80	186.90	96.00	45.00	45.00	37.10	14.80	896.90	58.40	29.10	245.10	224.50	-54.30	42.20
Salinity	mg/L	40	0	90	2070	830	530	6470	1240	960	610	480	290	670	9640

C - degrees Celsius

mg/L - milligrams per Liter

mV - milliVolts

NTU - Nephelometric Turbidity Units

uS/cm - micro-Siemens per centimeter

Distribution of Dissolved Arsenic

Dissolved arsenic concentrations in the samples obtained from the interior wells ranged from background levels (low of 0.003 mg/L) to 3.430 mg/L. The highest concentration was seen in the sample from MW-10 and the lowest concentration was seen in MW-10D. Thus, there was a two order of magnitude decrease in arsenic to background levels with depth at the MW-10/MW-10D well pair. The dissolved arsenic concentrations in the samples from MW-11 and MW-11D were 0.658 mg/L and 0.173 mg/L, respectively, representing a decrease in arsenic with depth at the MW-11/MW-11D well pair. Relatively high concentrations of arsenic do not correlate with relatively high SC. This is because SC can be high either from ash leachate or from salt water intrusion. The relatively high SC values at MW-10 (ranging from 3,099 to 3,549 µS/cm over the tidal study) are associated with ash leachate with an arsenic sample concentration of 3.430 mg/L. Whereas the other two wells with relatively high SC (MW-11D ranging from 3,771 to 3,774 µS/cm and MW-12 ranging from 11,845 to 12,235 µS/cm) associated with salt water intrusion had relatively low arsenic (0.175 and 0.003 mg/L, respectively). In the samples from the remaining two shallow interior monitoring wells, MW-1 and MW-4, arsenic concentrations were 0.453 and 0.142 mg/L, respectively.

Dissolved arsenic concentrations in the samples obtained from the near shoreline monitoring wells ranged from background levels in MW-12 to 0.701 mg/L in MW-7. The lowest concentration (0.003 mg/L) was at MW-12 located along the west southern shoreline of the peninsula. The highest concentrations of arsenic were in samples taken from MW-7 and MW-8 (0.701 and 0.547 mg/L, respectively), near the shoreline in the eastern portion of the Ash Site. The arsenic concentration in samples from the remaining four near shoreline wells ranged from 0.035 to 0.211 mg/L.

Distribution of Dissolved Barium

Dissolved barium concentrations for four of the six samples obtained from the interior wells ranged from 0.297 to 0.375 mg/L. Barium concentrations in samples collected from the other two interior well samples were less than the background concentration measured in the sample from MW-9 (0.042 mg/L). The variation in concentration with depth observed in the arsenic results for the MW-10 / MW-10D well pair was similar for barium with an order of magnitude decrease from the shallow well sample (0.337 mg/L) to the sample from the deeper monitoring well (0.040 mg/L). There was an order of magnitude increase in barium concentration with depth at the MW-11 / MW-11D well pair.

The dissolved barium concentrations in all near shore monitoring wells ranged from 0.016 to 0.044 mg/L, except for the result for MW-12. The barium result for MW-12 was 0.697 mg/L, or an order of magnitude higher than that seen in the samples from all of the other near shoreline monitoring well samples.

Dissolved Iron

Dissolved iron concentrations in samples collected from the interior monitoring wells ranged from 1.27 to 56.2 mg/L. The lowest concentration of dissolved iron was seen in the sample for MW-4 and the highest concentrations of dissolved iron were seen in the samples from the MW-11 / MW-11D well pair, 31.2 and 56.2 mg/L, respectively. Therefore, as seen in the results for barium, there was an increase in iron concentration with depth at this location. The same decrease in concentration seen with depth of sample for arsenic and barium at the MW-10 / MW-10D well pair, were seen in the iron results, with values of 9.66 mg/L for the shallow well sample and 6.65 mg/L for the deep well sample.

Dissolved iron in the samples from the near shore monitoring wells varied over two orders of magnitude from 0.211 to 25.5 mg/L. The lowest concentrations of iron were seen in the sample from MW-3 and MW-12 at 0.221 and 0.451 mg/L, respectively. Concentrations of iron in the 10s of mg/L were seen in the samples from MW-2, MW-6, MW-7, and MW-8 with the highest concentrations in the samples from MW-6 and MW-7 at 24.5 and 25.5 mg/L, respectively.

Dissolved Manganese

Dissolved manganese concentrations in the interior monitoring wells samples ranged from 0.122 to 2.08 mg/L with the highest concentration in the sample from MW-1. The range of manganese concentrations in the remaining five interior wells ranged from 0.122 to 0.474 mg/L. The variation with depth seen at the MW-10/MW-10D well pair was again a decrease from 0.315 mg/L in the shallow well sample to 0.122 mg/L in the deeper well sample. Again, a slight increase is seen with depth from the samples taken at the MW-11/MW-11D well pair (0.395 to 0.474 mg/L).

The variation in concentration of manganese for the near shoreline wells was 0.043 to 0.524 mg/L, with the two lowest values seen in samples from MW-3 and MW-5 at 0.428 and 0.077 mg/L, respectively. The remaining five results ranged in concentration from 0.129 to 0.524 mg/L with the highest manganese concentration seen in the sample from MW-6.

General Observations Concerning Water Quality Data

Close inspection of the water quality data reveals a few generalized relationships. In general, the wells that yielded samples with the highest concentrations of major ions (calcium, magnesium, sodium, and potassium) included MW-10, MW-11D, and MW-12. The highest values for arsenic, barium, and iron were also found in this group of wells. However, the next three highest values for these COIs were randomly distributed among the other wells having a range of major ion concentrations less than those found in MW-10, MW-11D, and MW-12. The highest value for manganese was found in the sample for MW-1, which had relatively low major ion concentrations.

3.3.5 Revised Conceptual Site Model

An initial CSM was presented in the RIWP Addendum (Shaw, 2010b), as discussed in Section 3.3.1. This representation considered three possible configurations to the water table aquifer within Burton Island; one with a subtle mounding of the water table causing lateral outward flow, one with more pronounced mounding of the water table causing lateral outward flow and possibly significant downward flow, and one with a depression in the water table causing inward flow during periods of high tide. Modifications to the CSM presented here represent findings related to WLE measurements and specific conductance measurements obtained during the tidal study. As discussed in Section 3.3.3.1, WLE measurements recorded during the course of the 19-day tidal study determined there was a subtle mounding of the water table in the interior of the peninsula all of the time. In addition, it was determined that inward and outward gradients were controlled by the water levels in the surrounding surface water bodies (**Figures 3.3-4, 3.3-5, and 3.3-6**). Based on the WLE data, inward water level gradients occurred between 32 and 49 percent of the time during the tidal study, depending on position along the shoreline of Burton Island. In contrast, the WLEs indicated that outward flow gradients were present 51 and 68 percent of the time during the tidal study.

During the tidal study the mounding of the water table in the interior of the peninsula was determined to be persistent and subtle (never more than 3.3 feet between the water levels in surrounding surface water bodies and shallow interior monitoring well MW-10). Based purely on these water level relationships, during the times when outward gradients are present there was a potential for groundwater to flow laterally towards the surrounding surface water bodies and not downward any significant distance into the Columbia sand aquifer. This is significant because domestic water wells inland of the Indian River shoreline, north of the peninsula and inland of the Island Creek shoreline south of the peninsula draw water from deeper portions of the Columbia sand aquifer and higher mounding of the water table on Burton island would represent a greater probability for Ash Site affected groundwater to enter these deeper portions of the aquifer. However, this is not the case.

An additional consideration in assessing flow paths are the effects of saline water intrusion. Based on the specific conductance data collected during the tidal study and salinity levels documented in the 316(a) report, the density of groundwater with Burton Island is persistently much lower than the density of the surrounding surface water bodies. The range of total dissolved solids content for the near surface groundwater on Burton Island is estimated to be less than 5,000 mg/L, except for groundwater proximal to MW-12, which has an estimated TDS of about 6,000 mg/L. The range of estimated total dissolved solids content for the surrounding surface water bodies was greater than 15,000 mg/L more than 95 percent of the time during the tidal study.

The persistent saline character of water in Indian River and Island Creek is affecting the density of groundwater underlying the surface water bodies within the Columbia sand aquifer causing a saline groundwater to intrude into the Columbia sand aquifer under Burton Island. Evidence of this is seen in the SC data for MW-11D and MW-12. Saline water intrusion conditions along a coastline are described by Fetter (2001, pp 327-338). When these conditions occur, a no flow boundary is created within a zone of diffusion where fresh-terrestrial groundwater interfaces with saline groundwater, limiting the outward flow of fresh water. This scenario is illustrated in **Figure 3.3-11**. In situations where there is a water table aquifer underlying a land mass of limited extent, such as the Burton Island peninsula, terrestrial fresh water recharge is limited and the surrounding saline water envelope may intrude to a greater extent. This effect on fresh groundwater flow paths is illustrated in the depiction of the revised CSM on **Figure 3.3-12**. In this improved version of the CSM, it is assumed that the vertical limit of effects of saline water intrusion would be the top of the zone of clay lenses and inclusions, reported to occur at -75 ft msl. Saline water has been consistently present in the Indian River embayment in the vicinity of Burton Island for at least the past ten years therefore there has been sufficient time for denser water of ocean origin to migrate less than 75 feet from the bottom of the surrounding surface water bodies to the top of the intermittent clay lens zone. Specific conductance measurements at MW-10D and MW-11D suggest that the effect of salt water intrusion is being felt at a higher elevation in the eastern part of Burton Island than in the western part of the Island. These observations are consistent with a salt water intrusion model as the eastern part of the island is more seaward and more narrow, therefore having less of a fresh water recharge area than at MW-10D.

Short duration discharges of less dense groundwater from Burton Island to the surrounding surface water bodies occur during those low tide conditions when the difference in elevation between groundwater and surface water surrounding surface water are greatest. As discussed in Section 3.3.4.2, these periods occurred less than 8 percent of the time at surface water monitoring stations SWG-1 and SWG-4, and less than 1 percent of the time at stations SWG-2 and SWG-5. The frequency of these occurrences recorded at SWG-1 and SWG-4 are considered more representative of the shoreline surrounding Burton Island as a whole because these stations were installed close to the shoreline and the other stations were further away from the shoreline. These temporary large downward shifts in specific conductance represent times when outward flow and mass loading of COIs to the surrounding surface water bodies are occurring. Mass loading estimates are described in the following section.

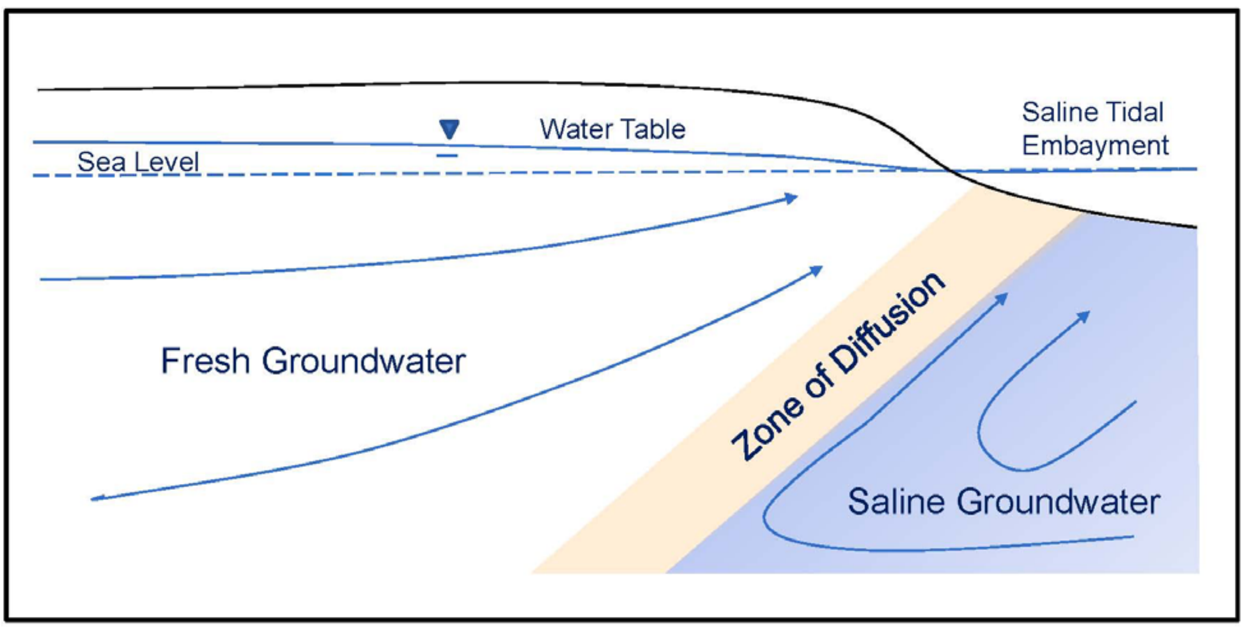

Figure 3.3-11 Circulation of fresh and saline groundwater at a zone of diffusion in a coastal aquifer (modified from Cooper, 1964, in Fetter, p.332; Applied Hydrogeology, 4th. Ed., 2001).

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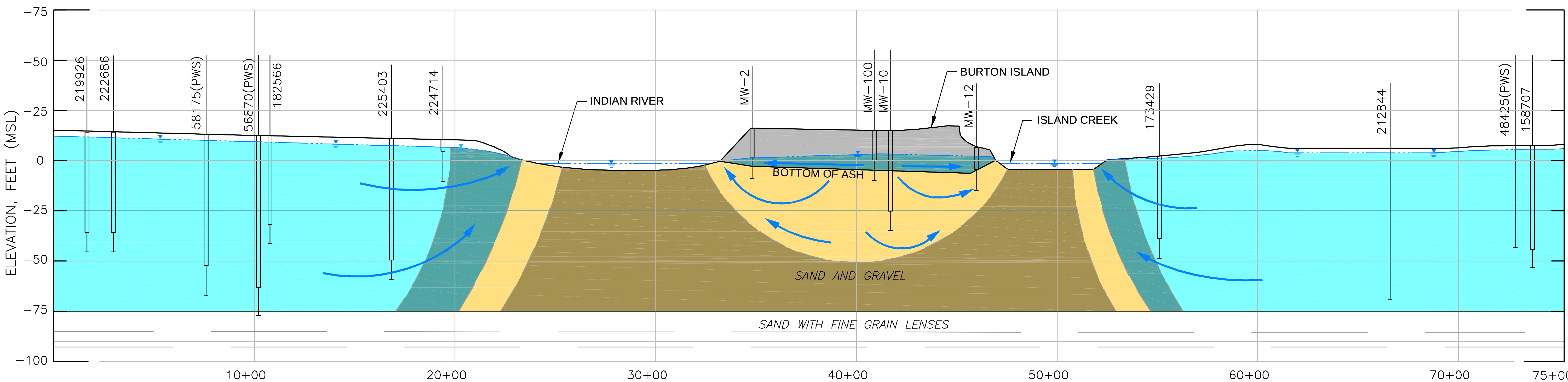
OFFICE Trenton, NJ

DRAWING NUMBER 19684028-B1



SPECIFIC CONDUCTANCE ZONES (uS/cm)

- 0
- 100
- 1000
- 10000
- 60,000

LEGEND:

WATER SUPPLY WELL

219926 — DNREC WELL NUMBER

CASING

PRODUCTION ZONE

(PWS) PUBLIC SUPPLY WELL (OTHERWISE DOMESTIC SUPPLY WELL)

APPROXIMATE POSITION OF WATER TABLE

GROUNDWATER FLOW PATH

VERTICAL SCALE

0 50 100 FEET

HORIZONTAL SCALE

0 500 1000 FEET

REV	DESCRIPTION / ISSUE	DATE	APPROVED

Shaw Shaw Environmental, Inc.

DESIGNED BY: --	NRG - INDIAN RIVER FACILITY BURTON ISLAND SUSSEX COUNTY, DELAWARE
DRAWN BY: B. Faison	FIGURE 3.3-12 CONCEPTUAL SITE MODEL
CHECKED BY: A. Steele	

APPROVED BY:	DATE:	SCALE:	DRAWING NO.	SHEET NO.
R. Wardrop	1/20/11	AS SHOWN	19684028-B1	--

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Xref:
Image: Burton_Island_extract_2.sid
scan0053.tif
scan0054.tif

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3.3.6 *Mass Loading Estimates*

As presented in Section 3.3.4.3, four COIs (arsenic, barium, iron, and manganese) were selected for mass loading estimates. Based on the CSM, outward groundwater flow and transfer of COIs into the surrounding surface water bodies can occur when outward WLE gradients are present. During these times, outward flow will be restricted by the density of surface water and groundwater near the shoreline. These conditions occurred 51 to 68 percent of the time over the 19 day the tidal study A subset of these times of outward gradients are times when less dense groundwater flow out of Burton Island affects the density of the surrounding surface water bodies. These events were manifested by large downward shifts in SC at the surface water monitoring points, which occurred less than eight percent of the time during the tidal study. Based on these observations the mass loading estimates for COIs are being presented as a range. The lower end of the range is derived from times when the discharge of less dense groundwater could be documented at the surface water monitoring points. The upper end of the range is derived from all times when outward gradients were present, regardless of the SC values being recorded at the surface water monitoring points. The lower end of the range is considered more representative of loading as there is a measureable change in surface water chemistry when mass loading is occurring.

Estimates of COI loading to the surrounding surface water bodies were made using equation (1).

(1) $L = Q \times C;$

Where:

Q = outward flow = $(K \times b) \times I \times L$

K = hydraulic conductivity

b = saturated thickness of aquifer through which flow is occurring

I = water level gradient

L = the length of shoreline along which flow is occurring

C = dissolved COI concentration in the samples collected August 2 and 3, 2010

The hydraulic conductivity (K) was determined by slug testing results for the five new monitoring wells. The results of the slug test analyses are presented in **Appendix H**. The results were relatively consistent between wells and ranged from 8.52×10^{-5} to 5.22×10^{-3} cm/sec. For purposes of the mass loading estimates, the average K value for all tests of 1.80×10^{-3} cm/sec was used.

The saturated thickness (b) was set at 85 feet. This value was estimated based on specific conductance values in the 50-foot deep monitoring wells, which were still in the brackish water range and the expectation that the vertical boundary between the less dense waters and saline waters should occur a short distance below that; and the expected occurrence of the intermittent fine grained lenses at the bottom of the Columbia sand aquifer creating an aquitard at an elevation of approximately -75 ft msl.

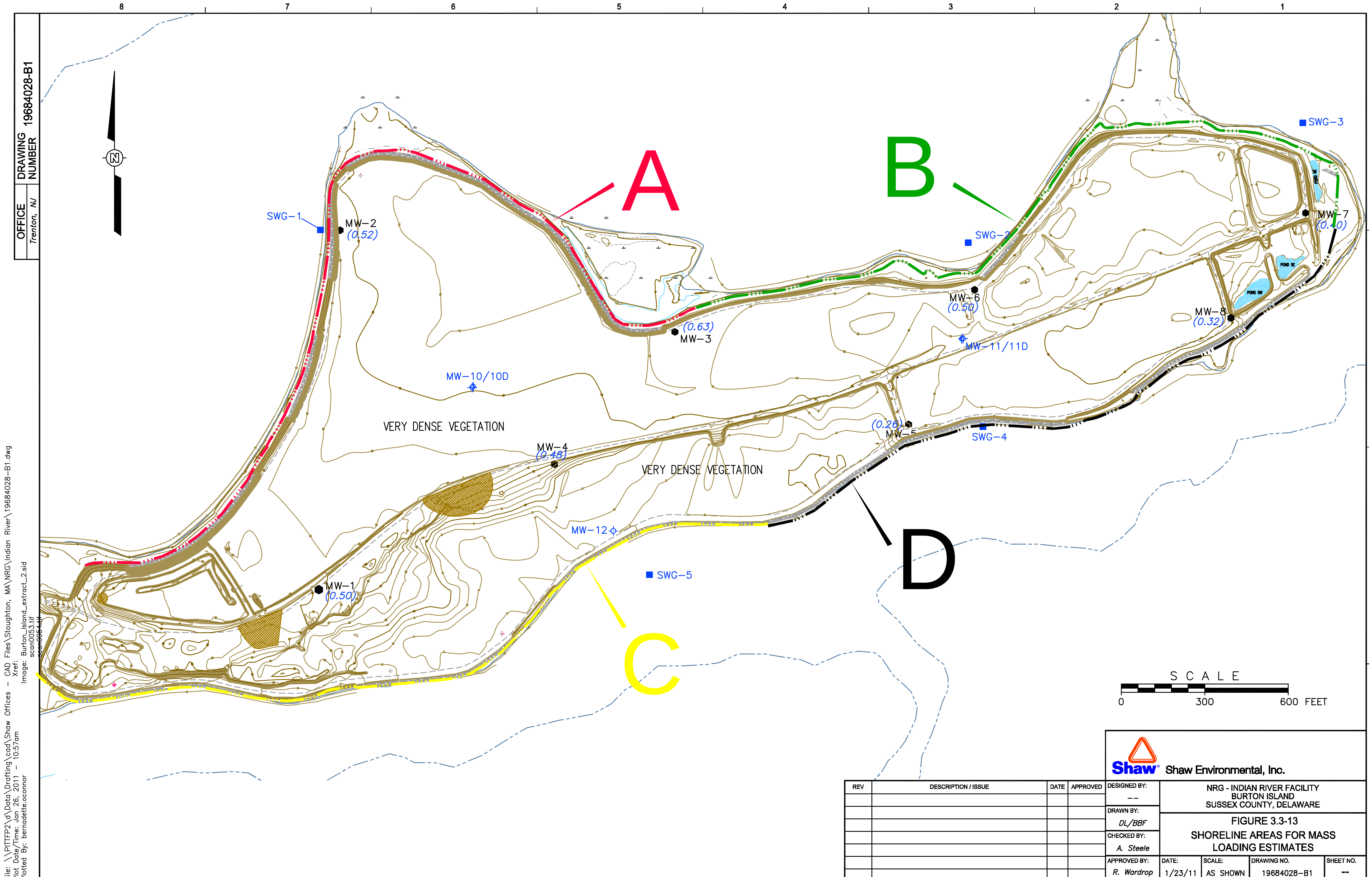
For length (L), the perimeter of Burton Island was divided into four lengths of shoreline for which mass loading was estimated. These four lengths of shoreline are shown on **Figure 3.3-13**.

The gradients (I) were determined for each time interval by dividing the difference in water elevation between the surface water monitoring point and the near shore monitoring well for a particular 30-minute time period by the distance between the near shore monitoring well and the shoreline. Thus, a different gradient was determined for each 30-minute time interval.

For concentration (C), the sample COI concentrations for monitoring wells along each length of shoreline were averaged. The dissolved COI concentrations from the analytical results of the August 2-3, 2010 sampling event were used to derive these values.

The mass loading calculations are provided in **Appendix I** and a summary of the input values and results are presented on **Table 3.3-7**. Mass loadings for times when inward flow was occurring were set to zero. The mass loading determined for each 30 minute interval for each section of shoreline were calculated and summed, and then the total loadings were calculated by summing the loadings for all four shoreline sections. This provided a total loading estimate for the 19-day tidal study for each COI. This total was then divided by 19 to give the loading per day which is expressed in pounds per day.

An underlying assumption of the mass loading calculation is that dissolved COIs pass from Burton Island groundwater into the surface water bodies without any chemical reactions that might precipitate a COI or otherwise retard transport and reduce the loading. Thus, these estimates are considered conservative in that chemical reactions are likely occurring at the groundwater / surface water interface.



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SWG-5
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CHECKED BY:
A. Steele
APPROVED BY:
R. Wardrop
NRG - INDIAN RIVER FACILITY
BURTON ISLAND
SUSSEX COUNTY, DELAWARE
FIGURE 3.3-13
SHORELINE AREAS FOR MASS LOADING ESTIMATES
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Table 3.3-7

Results of Mass Loading Estimates

Input Parameters:					
	Hydraulic conductivity (K)		1.83 x 10-3	cm/sec	
	Saturated thickness (b)		85	feet	
	Shoreline Section Length (L) (ft)	**Average Concentration Along Shoreline Section (C) (mg/L)**			
		Arsenic	**Barium**	**Iron**	**Manganese**
Section A	3,456	0.123	0.025	5.86	0.136
Section B	2,864	0.295	0.033	16.74	0.261
Section C	2,885	0.033	0.368	1.70	0.143
Section D	2,435	0.437	0.029	13.02	0.141
Loading Results:					
Arsenic	0.067 to 0.366	pounds per day			
Barium	0.042 to 0.258	pounds per day			
Iron	1.76 to 14.12	pounds per day			
Manganese	0.037 to 0.280	pounds per day			

3.3.7 Findings

The following findings were drawn from the 19-day tidal study results:

1. Water levels at the surface water monitoring points (SWG-1, SWG-2, SWG-4, and SWG-5) varied between a range of 3.31 to 3.46 feet in response to twice daily high tide and low tide conditions.
2. Water levels at interior groundwater monitoring well MW-10 ranged from 0.87 to 2.29 ft msl and at interior deep well MW-10D from -0.28 to 1.45 ft msl in response to twice daily high tide and low tide conditions.
3. Water levels in the shoreline wells (MW-2, MW-6, and MW-12) ranged from -0.82 to 1.36 ft msl.
4. Vertical flow gradients measured at well pair MW-10/MW-10D were downward and relatively small with values ranging from 0.016 to 0.081.
5. The water levels in all monitoring wells, including interior monitoring wells MW-10 and MW-10D responded directly to tidal fluctuations in Indian River.
6. The horizontal gradients for the SWG-1/MW-2, SWG-2/MW-6, and SWG-5/MW-12 monitoring point pairs were similar and indicate an inward gradient 32 to 49 percent of the time and outward flow 51 to 68 percent of the time during the tidal study.
7. The surface waters surrounding Burton Island are saline in character (estimated TDS between 15,000 and 30,000 mg/L) more than 92 percent of the time. The TDS

estimated for all of the monitoring wells was generally much lower. The water in MW-2 remained brackish (in the range from 1,000 to 5,000 mg/L TDS) for the entire tidal study. The water in MW-6 remained fresh (less than 1,000 mg/L TDS) for the entire tidal study and the water in MW-12 remained just inside the lower limit of the highly brackish category (range from 5,000 to 15,000 mg/L TDS) for the entire tidal study.

8. At the monitoring well pair MW-10/MW-10D the shallow groundwater was brackish and the deeper groundwater was fresh 100 percent of the time. This relationship was reversed at the MW-11/MW-11D well pair where the shallow groundwater was fresh and the deeper groundwater was brackish 100 percent of the time. The more dense groundwater at depth at the MW-11/MW-11D well pair is attributed to the effects of saline water intrusion moving east to west under a less dense groundwater zone under Burton Island. The more dense groundwater close to the surface at the MW-10/MW-10D well pair is attributed to ash leachate.

9. Burton Island groundwater is fresh to brackish in quality and it is surrounded by saline surface water bodies. Fresh water influxes from the inland portion of the Columbia Formation aquifer during low tide conditions do not have a significant effect on the total dissolved mineral content of the surface water bodies, which is saline most of the time.

10. The surface water monitoring stations were saline more than 92 percent of the time during the study period. Water of significantly less TDS was indicated at the surface water monitoring stations a small percentage (less than 8 percent) of the time during the study period.

11. Groundwater sampling of all monitoring wells was performed on August 2 and 3, 2010. Based on the frequency of detections above background and above the URS for surface water for the dissolved fractions of metals, arsenic, barium, iron, and manganese were carried forward for mass loading assessment.

12. Dissolved arsenic concentrations in the samples obtained from the interior wells ranged from background levels to 3.43 mg/L. The highest concentration was seen in the sample from MW-10 and the lowest concentration was seen in MW-10D. Thus, there was more than a two order-of-magnitude decrease in arsenic with depth to background levels at the MW-10/MW-10D well pair. The dissolved arsenic concentrations in the samples from MW-11 and MW-11D were 0.658 mg/L and 0.173 mg/L, respectively, which also demonstrates a significant decrease in arsenic

with depth at the MW-11/MW-11D well pair. The arsenic concentrations from the remaining two shallow interior monitoring wells, MW-1 and MW-4 were 0.453 and 0.142 mg/L, respectively.

13. Dissolved arsenic concentrations in the samples obtained from the near shoreline monitoring wells ranged from background levels in MW-12 to 0.701 mg/L in MW-7. The lowest concentration (0.003 mg/L) was at MW-12 located along the west southern shoreline of the peninsula. The highest concentrations of arsenic were in samples taken from MW-7 and MW-8 (0.547 and 0.701 mg/L, respectively), near the shoreline in the eastern portion of the Ash Site. The arsenic concentration from the remaining four near-shoreline wells ranged from 0.035 to 0.211 mg/L.

14. The variation of dissolved metals among monitoring well samples is shown on **Table 3.3-6**. For barium, iron, and manganese, there was a concentration decrease with depth seen at the MW-10 / MW-10D well pair and a concentration increase with depth seen at the MW-11 / MW-11D well pair.

15. During the tidal study, the mounding of the water table in the interior of the peninsula was determined to be present all of the time, but subtle with never more than 3.32 feet between the water levels in surrounding surface water bodies and shallow interior monitoring wells.

16. In situations where there is a water table aquifer underlying a land mass of limited extent, such as the Burton Island peninsula, terrestrial fresh water recharge is limited and the surrounding saline water envelope restricts the outward flow of fresh groundwater. This effect on fresh groundwater flow paths is illustrated in the depiction of the revised CSM on **Figure 3.3-12**. Due to this effect there would be no flow path and thus no pathway of exposure from groundwater affected by leachate on Burton Island to water supply wells inland of the north shoreline of Indian River, north of Burton Island or to water supply wells inland of the south shoreline of Island Creek, south of Burton Island.

17. A range of COI mass loading estimates were made for Indian River and Island Creek. The lower end of the range is calculated using times when dramatic SC decreases were recorded at the surface water monitoring points and the upper end of the range includes all times when an outward gradient was present. The lower end of the range is considered more representative of actual loading because the time of loading is apparent. Other times when outward gradients are present, flow and discharge would

be restricted by the high density of the receiving waters. The range of estimated mass loading rates are listed as follows:

Arsenic	0.067 to 0.366 pounds per day
Barium	0.042 to 0.258 pounds per day
Iron	1.757 to 14.118 pounds per day
Manganese	0.037 to 0.280 pounds per day

18. The mass loading estimates are based, in part, on a selected saturated thickness (b) through which transport is occurring. The value was set at 85 feet based on the expected position of the zone of diffusion and expected position of the base of the Columbia sand aquifer (characterized by the transition from sand and gravel to lenses or pockets of green silty clay interspersed with coarse sand) from studies proximal to Burton Island.
19. An underlying assumption of the mass loading calculation is that dissolved COIs pass from the fresh water system into the surface water bodies without any chemical reactions that might precipitate or otherwise reduce the loading to the surface water. This assumption is conservative. There are likely some differences in the chemistries of the fresh groundwater affected by coal ash, the pore water in the sediments of the surrounding surface water bodies, and the saline surface waters themselves. These differences are likely to induce chemical reactions that would reduce the concentrations of certain COIs passing from groundwater to surface water during the times of outward flow.
20. Now that the CSM has been improved, there is an understanding of when and to what extent mass loading occurs. The estimates are conservative and the loading results are small and, for this reason, the mass loading would not be expected to have an adverse effect on surface water quality, as was demonstrated by surface water samples collected during the FE (Shaw, 2008).

3.4 Overland Flow Pathway

Although not identified in the RIWP or RIWP Addendum, DNREC-SIRB requested the following additional evaluation: calculate and provide a preliminary mass loading estimate for arsenic to Island Creek and Indian River from Burton Island, via the overland flow pathway. A similar evaluation of the subsurface flow pathway was discussed in Section 3.3.6. The overland flow pathway was evaluated using the Revised Universal Soil Loss Equation (RUSLE). The preliminary analysis is provided in **Appendix J**.

The analysis estimates the soil loss from three scenarios: existing conditions, post-construction, and established cover. The ‘existing conditions’ scenario represents the condition as of the end of the first phase of shoreline stabilization activities but prior to the second phase of construction, or late 2009 to early 2010. The ‘post-construction’ scenario represents the anticipated condition at the completion of the second phase of shoreline stabilization activities when all but the eastern tip of the Ash Site shoreline will be stabilized, or late 2011. The ‘established cover’ scenario represents a future time one or two growing seasons after the construction is complete and vegetation has become established in previously disturbed work areas.

Based on the topography of the Ash Site, the analysis estimates the soil loss from the perimeter access road constructed on the top of the berms, across the vegetated shoreline slope and revetment to the water’s edge. The lengths and areas vary in the three scenarios. The land inside the perimeter access road is typically sloped such that runoff would not be transported towards the water; therefore, the interior area is not included in the soil loss estimate. The analysis indicates that the total soil loss will be reduced by 99.8% from ‘existing conditions’ to ‘established cover’ conditions. The analysis confirms that the contribution of Ash Site material to the surrounding surface waters is significantly reduced by the shoreline stabilization project. As such, the condition of no significant risk from exposure to surface water and sediment as described in the FE and supported with empirical data, is not anticipated to change due to potential overland flow contribution.

In order to translate the estimated soil loss via overland flow to a mass loading estimate of arsenic, the contribution of ash in soil and concentration of arsenic in ash are considered. Only a portion of the total estimated soil loss is potentially ash material. The revetment is rip rap, the shoreline slopes are covered with imported topsoil and vegetation, and the access road consists of a mixture of ash, sand, and gravel. Thus, ash can only erode from the access roads in this analysis. Even with the conservative assumption that the road material is entirely ash, ash is at most 7.4% of the total estimated soil loss under the established cover scenario. And, assuming an arsenic concentration in ash of 150 mg/kg (based on surface soil samples), an estimated 0.09 pounds of arsenic are eroded in ash from access roads each year. Furthermore, this approach evaluates only the loss from the road and does not consider the filtering effects which will occur as the runoff from the road moves through the vegetated slope and then the rip rap before reaching the water. Therefore, it is anticipated that the actual mass of arsenic reaching the water is far less than these conservative estimates indicate. Additionally, the FE identified no significant risk from exposure to sediment and surface water when the shoreline was eroding (i.e., prior to the implementation of the shoreline stabilization project) and this model demonstrates that the contributions of soil, ash, and arsenic from erosion are significantly reduced.

3.5 Analytical Data QAQC

A Level III data validation was performed for inorganic, wet chemistry, and radiological analytical data received from the laboratory. The compiled data validation report is provided in **Appendix K**. The overall quality of the data was determined to be acceptable with minimal qualification. No data were rejected. The actions and qualifiers identified by the data validation have been incorporated into results summary tables provided throughout this report. Only validated data was used in preparing the evaluations presented in this report and the conclusions thereof.

In addition to the data validation, the electronic data deliverables (EDDs) from the laboratory were reviewed to ensure they meet the DNREC-required EQuIS 5 Professional database format. The data validation qualifiers have been added to the EDDs. The EDDs are included on the compact disc accompanying this report.

4.0 Air Dispersion Modeling

Air Dispersion Modeling was performed as per the RIWP. This section describes the approach, model inputs, and results. As the air dispersion modeling backup (e.g., model setup, screen shots, etc.) is not easily formatted for printing in hard copy, the information is provided on the compact disc included with this report.

4.1 Approach

Atmospheric dispersion modeling was performed as a means of estimating ambient particulate matter (PM) concentrations and dry deposition rates in the local area due to potential wind erosion from OU2. The PM ambient concentrations were estimated for Total Suspended Particulates (TSP), PM with aerodynamic diameter less than a nominal 10 micrometers (PM_{10}), and PM less than 2.5 micrometers ($PM_{2.5}$) along with dry deposition rates. The estimated PM concentrations and dry deposition rates were used as input to a risk assessment. The modeling was carried out in phases starting with a conservative screening level modeling analysis followed by more realistic refined level modeling.

The first step in the analysis was to characterize the potential windblown PM emissions from the surface of OU2 using the USEPA's Compilation of Air Pollutant Emission Factors - Volume 1: Stationary Point and Area Sources, also known as AP-42. The specific methodology to calculate the PM emissions was taken from AP-42 Chapter 13.2.5, Industrial Wind Erosion, which uses a threshold wind speed above which windblown emissions of surface erodible material occur along with wind speed data from a representative weather station. The threshold wind speed was determined using a site-specific method involving a hand sieve field procedure to determine the mode of the loose surface material (i.e., 0 to 1 cm) aggregate size distribution by inspection of relative sieve catch amounts. As a realistic scenario, the portion of OU2 consisting of un-vegetated areas were included in the PM emissions estimates with no consideration of dust control and the vegetated areas were conservatively assumed to be controlled at an efficiency of 99 percent, even though these vegetated areas are not expected to have any PM emissions. At DNREC's request, as a conservative worst case scenario, OU2 was also modeled assuming that it is entirely bare ash with no vegetative cover. However, the potential for OU2 to be entirely void of vegetation or even vegetative debris (as might result from a fire) is remote. The wind speed data were obtained from observations collected at Georgetown Sussex County Airport located approximately 10 miles northwest of Burton Island. Five years of hourly wind speeds (i.e., 2004

– 2008) were inserted into a spreadsheet that performs the AP-42 Industrial Wind Erosion calculations to develop an hourly emission rate file for each year of data. Using hourly wind speed data for the wind erosion calculations is a reasonable approach in that the Automated Surface Observing System (ASOS) used at airports records a 2-minute average wind speed to represent each hour, which is the averaging time that matches well with the half life of the erosion process according to AP-42.

Given the estimated PM emission rates as a function of 2-minute wind speeds, the USEPA sponsored SCREEN3 dispersion model was first used to conservatively estimate PM concentrations at various downwind distances to obtain the maximum impacts. The entire island was modeled as an area source using rectangular dimensions that approximated the surface area of the island. The SCREEN3 calculated maximum 1-hour PM concentrations were adjusted to annual and 24-hour average concentrations using the factors 0.05 and 0.4, respectively, based on the USEPA "Screening Procedures for Estimating the Air Quality Impact of Stationary Sources, Revised".

The AERMOD dispersion model was then run as a refined analysis of the fugitive PM impacts using the five years of hourly surface meteorological data and twice daily upper air data, along with digital terrain data for the receptor grid, to obtain more realistic PM concentrations and dry deposition rates to the ground and water at a network of receptors surrounding the disposal area. The fugitive PM emission rates were entered using an hourly emission rate file for each year of meteorological data. Dry deposition was treated using Method 2 along with a fine mass fraction of 0.075 based on AP-42 Chapter 13.2.5 and representative mass-mean aerodynamic particle diameter of 10 microns.

4.2 Model Inputs

As indicated earlier, the first step in the modeling analysis was to characterize the potential windblown PM emissions from the surface of OU2 using the methodology of the USEPA's AP-42 Chapter 13.2.5, Industrial Wind Erosion. The threshold wind speed was determined using a site-specific method involving a hand sieve field procedure used to determine the mode of the loose surface material (i.e., 0 to 1 cm) aggregate size distribution by inspection of relative sieve catch amounts. The hand sieve field procedure was conducted at the three distinct bare ash areas of the island where samples were scraped from the surface and submitted to Shaw's geotechnical laboratory for hand sieve using specialized size sieves. The results of the hand sieve procedure for the three bare ash areas are summarized in **Table 4-1** and the report is included in **Appendix**

L. They indicate that the mode of the particle size distribution can best be represented by the 0.25 millimeter sieve size, resulting in the lowest possible threshold friction velocity of 43 centimeters per second.

Table 4-1

Particle Size Analysis Results of Hand Sieve Field Procedure

	Lab Sample No.	SEK 4828	SEK 4829	SEK 4830
Sieve No.	Diameter (mm)	Percent Finer	Percent Finer	Percent Finer
#5	4.00	81.7%	92.8%	67.3%
#10	2.00	67.1%	90.3%	59.0%
#18	1.00	52.4%	83.9%	52.1%
#35	0.500	41.9%	70.6%	43.5%
#60	0.250	32.8%	54.5%	36.0%

mm - millimeter

Input data used by the SCREEN3 model include: emission type and source parameters, a matrix of meteorological conditions, and downwind receptor spacing. The entire island was modeled as an area source using rectangular dimensions that approximated the surface area of the island. Based on the five years of hourly wind speed data and the AP-42 PM emissions methodology, only wind speeds of 8 meters per second (m/sec) through 15 m/sec would result in wind-blown PM emissions. Therefore, the PM emission rates associated with the individual wind speeds between 8 and 15 meters per second (m/sec) were used in the SCREEN3 model along with the corresponding wind speeds and D atmospheric stability class to determine the worst case PM concentrations for TSP, PM_{10} and $PM_{2.5}$. Only D stability class is appropriate for these higher wind speeds. Receptors were specified at 100 meter intervals out to a downwind distance of 2,000 meters.

For the AERMOD modeling analysis, OU2 was divided into 16 area sources in order to obtain reasonable area source dimensions. The three distinct bare ash areas of the island were included separately as individual area sources. A PM hourly emission rate file for each year of meteorological data along with the 5-year meteorological database (i.e., 2004 – 2008) was used in the analysis, including hourly surface observations from Georgetown Sussex County Airport located approximately 10 miles northwest of Burton Island and concurrent twice daily upper air data from Wallops Island, VA. The digital terrain data for the receptor grid (i.e., 1 arc-second) were obtained from the National Elevation Dataset (NED) developed by the U. S. Geological

Survey (USGS). The receptor grid was arranged as a polar grid with a radial for every 10 degrees azimuth of wind direction (i.e., 36 radials). Downwind rings of 100-meter spacing from 100 meters to 5,000 meters were used in the AERMOD modeling. The receptor grid was set relative to an origin located at the far southwest corner of the island. The latest USEPA AERMOD Implementation Guide dated March 19, 2009 was followed in processing the meteorological and terrain data.

4.3 Model Output

The results of the conservative SCREEN3 screening modeling analysis are summarized in **Table 4-2**. This table shows the highest predicted annual average and 24-hour average TSP, PM_{10}, and $PM_{2.5}$ concentrations from among all of the meteorological conditions and downwind receptors examined for both the realistic (i.e., vegetative cover considered) and worst case (i.e., entirely bare ash) scenarios.

Table 4-2

Screening Modeling Maximum Ground Level Concentrations

	NAAQS		**Realistic Scenario Vegetated Cover Included**		**Worst Case Scenario Entirely Bare Ash**	
Pollutant	**Annual (µg/m^3)**	**24-Hour (µg/m^3)**	**Annual (µg/m^3)**	**24-Hour (µg/m^3)**	**Annual (µg/m^3)**	**24-Hour (µg/m^3)**
TSP	--	--	18.6	148.6	1,860	14,860
PM_{10}	--	150	9.3	74.3	930	7,430
$PM_{2.5}$	15.0	35.0	1.4	11.1	140	1,110

µg/m3 - micrograms per cubic meter.
NAAQS – National Ambient Air Quality Standards
TSP – total suspended particulates
PM – particulate matter

The AERMOD modeling results were used to obtain the maximum annual average and 24-hour average TSP, PM_{10}, and $PM_{2.5}$ concentrations and maximum annual average dry deposition rates from among the five years of meteorological data examined. The AERMOD results for the three sensitive receptors that are closest to the southwest corner of the island, as determined from satellite photos, are summarized in **Tables 4-3 and 4-4** for both the realistic and worst case scenarios. The National Ambient Air Quality Standards (NAAQS) for PM_{10}, and $PM_{2.5}$ are provided in **Table 4-3** as a reference.

Table 4-3

Maximum Ground Level Concentrations at Three Closest Sensitive Receptors

Pollutant	NAAQS (µg/m^3)	Averaging Time	200 meters SW (µg/m^3)	400 meters S (µg/m^3)	1,000 meters NE (µg/m^3)
Realistic Scenario - Vegetated Cover Included					
TSP	**--**	Annual	0.46	0.20	0.27
PM_{10}	**--**	Annual	0.23	0.10	0.13
$PM_{2.5}$	**15.0**	Annual	0.034	0.015	0.016
TSP	**--**	24-Hour	66.3	24.3	13.4
PM_{10}	**150**	24-Hour	33.1	12.1	6.7
$PM_{2.5}$	**35.0**	24-Hour	5.0	1.8	0.8
Worst Case Scenario – Entirely Bare Ash					
TSP	**--**	Annual	12.5	5.5	9.3
PM_{10}	**--**	Annual	6.2	2.8	4.6
$PM_{2.5}$	**15.0**	Annual	0.94	0.41	0.70
TSP	**--**	24-Hour	1,660	636.9	517.6
PM_{10}	**150**	24-Hour	830.1	318.4	258.8
$PM_{2.5}$	**35.0**	24-Hour	124.5	47.8	38.8

Note: Distances measured from southwest corner of OU2.
24-Hour concentrations are the highest first highest values
µg/m3 - micrograms per cubic meter.

Table 4-4

Maximum Dry Deposition at Three Closest Sensitive Receptors

Pollutant	Averaging Time	200 meters SW (µg/m^3)	400 meters S (µg/m^3)	1,000 meters NE (µg/m^3)
Realistic Scenario - Vegetated Cover Included				
TSP	Annual	0.038	0.02	0.023
Worst Case Scenario – Entirely Bare Ash				
TSP	Annual	1.03	0.4	0.83

Note: Distances measured from southwest corner of OU2.
µg/m3 - micrograms per cubic meter.

4.4 Findings

Although fugitive dust generation and transport via air dispersion is a potential transport mechanism for constituents in surface soil at Burton Island, this transport mechanism is considered to be negligible. The results of this fugitive dust generation and dispersion analysis show that concentrations of PM10 and PM2.5 are expected to be less than their respective NAAQS at the closest sensitive receptor locations assuming Burton Island remains vegetated at its current level. This result is utilized in the human health risk assessment to eliminate this potential exposure pathway from further consideration.

5.0 Human Health and Screening Level Ecological Risk Assessment

A human health risk assessment (HHRA) and a SLERA were conducted as part of the FE that was completed for the Ash Site (Shaw, 2008). Review of the risk assessments in the FE resulted in the identification of several data gaps in the risk assessments for OU2. This section of the RI report presents the revised HHRA and SLERA for OU2. The human health and ecological risk assessments presented within this section have been conducted in accordance with guidance set forth in the *Remediation Standards Guidance under the Delaware Hazardous Substance Cleanup Act* (DNREC, 1999). Section 5.1 presents the human health risk assessment. Section 5.2 presents the screening level ecological risk assessment.

5.1 Human Health Risk Assessment

The HHRA for OU2 (area landward of shoreline sediments) was conducted in order to provide information for the following purposes:

- Refine assumptions regarding OU2 that were used in the FE (Shaw, 2008);
- Fill data gaps; and
- Provide sufficient information to make informed management decisions regarding closure of OU2 under the VCP.

As such, this HHRA will utilize data collected as part of the FE (Shaw, 2008) and also data collected specifically for this remedial investigation. The HHRA presented herein has been prepared in accordance with the guidance set forth in the *Remediation Standards Guidance under the Delaware Hazardous Substance Cleanup Act* (DNREC, 1999) and the *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part A* (USEPA, 1989). The following sections describe the methodologies that were used in conducting the human health risk assessment for OU2.

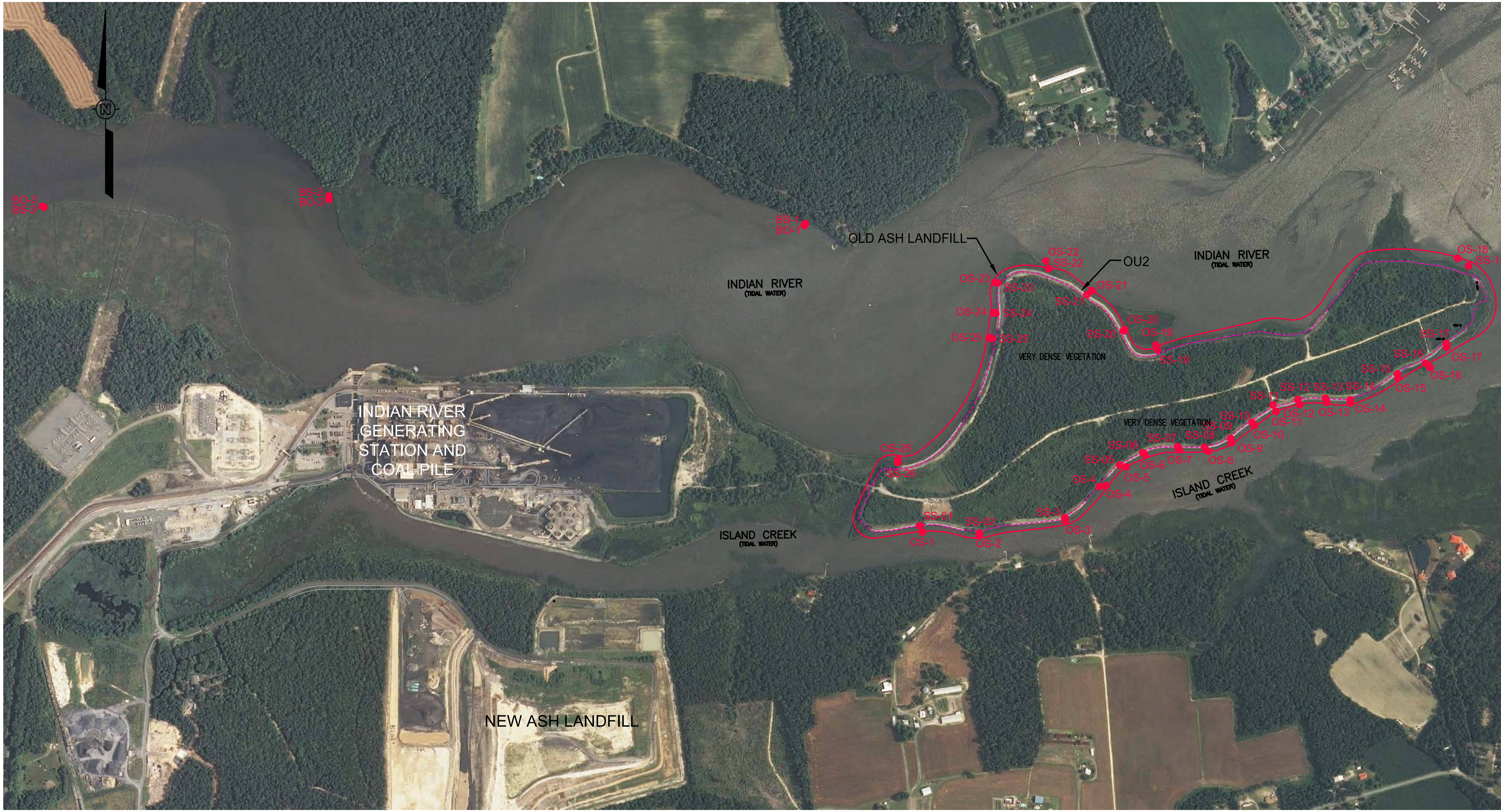
5.1.1 Data Collection and Evaluation

As stated previously, some of the data collected as part of the FE (Shaw, 2008) were utilized in this RI as well as data collected specifically for this RI. Specifically, sediment data collected during the FE and surface soil data collected for this RI were used to characterize potential human exposures at the Ash Site. Sediment samples were collected from Indian River and Island Creek in OU1 and OU3 in order to characterize the shoreline and near offshore environment. A total of fifty-two (52) sediment samples were collected from the top six (6) inch depth increment and analyzed for TAL metals. Per DNREC request, all of the sediment samples were collected and sent to the DNREC laboratory in New Castle, Delaware for organic compounds screening. All of the sediment samples were semi-quantitatively analyzed by gas chromatography/mass spectrometry (GCMS) for organic compounds to determine if a full quantitative organic analysis was appropriate. Based on the results of the organic screening conducted by DNREC, none of the samples required quantitative organic analysis. Five of the sediment samples were quantitatively analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides and polychlorinated biphenyls (PCBs) in order to determine the quantitation level for the organic analyses.

Twenty-six (26) sediment sample locations were identified in OU1 where the shoreline had been classified as exhibiting moderate or severe erosion. These sediment samples were collected in order to characterize the sediment along the shoreline where erosion was visually evident and where “worst-case” conditions were assumed to exist. An additional twenty-six (26) sediment samples were collected approximately twenty (20) feet offshore from the shoreline sediment sample locations. These twenty-six offshore sediment samples were collected in order to characterize the near-shore sediment environment and to help determine if sediment migration was occurring into the offshore environment. Three shoreline and three offshore sediment samples were also collected from background locations on Indian River, upstream of the Indian River Generating Station, in order to characterize background sediment conditions in Indian River in the vicinity of the Burton Island. The locations of the shoreline, offshore, and background sediment samples are presented in **Figure 5.1-1**.

In general, metals were routinely detected in all of the sediment samples. Organic compounds (VOCs, SVOCs, pesticides, and PCBs) were not detected in any of the sediment samples, with the exception of one detection of phenol at a concentration of 0.059 mg/kg at sediment sampling location BO-1 (a background sediment sampling location). None of the other sediment samples exhibited detectable concentrations of any of the organic compounds that were analyzed. These results verify the results of the organic screening analyses conducted by DNREC.

Surface soil on Burton Island was characterized through the collection and analysis of 14 composite surface soil samples. The locations where surface soil samples were collected are presented in **Figure 3.1-1** and the methodology for the sampling is described in Section 3.1.2.



LEGEND:

- FE SEDIMENT SAMPLE LOCATION
  - SS – SHORELINE SEDIMENT
  - OS – OFFSHORE SEDIMENT
- BACKGROUND SEDIMENT SAMPLE LOCATION
  - BS – BACKGROUND SHORELINE SEDIMENT
  - BO – BACKGROUND OFFSHORE SEDIMENT

SCALE

0 720 1440 FEET

REFERENCE: STREETMAP USA

File: \\PITTFP2\d\Data\Drafting\cad\Shaw Offices – CAD Files\Stoughton, MA\NRG\Indian River\19684028-B1.dwg
Plot Date/Time: Dec 22, 2010 – 10:07am
Plotted By: bernadette.oconnor
Xref:
Image: Burton_Island_extract_2.sid
indian_river-2.tif

OFFICE: Trenton, NJ

DRAWING NUMBER: 19684028-B1

Shaw Environmental, Inc.

REV	DESCRIPTION / ISSUE	DATE	APPROVED

DESIGNED BY: --	NRG - INDIAN RIVER FACILITY BURTON ISLAND SUSSEX COUNTY, DELAWARE
DRAWN BY: DL/BBF	FIGURE 5.1-1
CHECKED BY: A. Steele	2007 FE SEDIMENT SAMPLING LOCATIONS

APPROVED BY:	DATE:	SCALE:	DRAWING NO.	SHEET NO.
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5.1.2 Identification of Constituents of Potential Concern

Constituents of potential concern (COPCs) for which carcinogenic risks and non-carcinogenic health hazards are quantified in a human health risk assessment are routinely identified through various screening procedures. DNREC guidance presented in *Remediation Standards Guidance Under the Delaware Hazardous Substance Cleanup Act* (DNREC, 1999) suggests identifying COPCs by comparing detected concentrations of constituents to appropriate URSs. This was the method used for identifying COPCs in surface soil. However, DNREC does not provide sediment URS values for the protection of human health; therefore, an alternative screening procedure was necessary for screening sediment constituents in this assessment.

5.1.2.1 COPCs in Shoreline and Offshore Sediment

For this assessment, COPCs in sediment are identified as those constituents that are identified as "Important Bioaccumulative Compounds" by USEPA (2000a) and whose maximum detected concentration exceeds local background concentrations. Constituents that are not bioaccumulative would not transfer significantly from sediment to biota and would not be expected to be found in the tissues of fish/shellfish to any significant extent. The USEPA (2000a) has compiled a list of bioaccumulative compounds of potential concern based on input from the Bioaccumulation Analysis Workgroup and a review of various Agency documents. These constituents are known to be found in sediment in the vicinity of affected sites and in animal tissues at levels associated with toxic effects, and are referenced in other USEPA documents as being bioaccumulative.

Tables 5.1-1 and 5.1-2 present the summaries of the sediment data for shoreline and offshore sediment samples, respectively. As shown in **Tables 5.1-1 and 5.1-2**, the constituents that have been identified as preliminary COPCs in shoreline and offshore sediment are the nine constituents listed below. These constituents in sediment are quantitatively assessed in the HHRA for the Ash Site.

- Arsenic
- Cadmium
- Chromium
- Copper
- Lead
- Mercury
- Nickel
- Selenium
- Zinc

Table 5.1-1

Identification of Constituents of Potential Concern in Shoreline Sediment

Parameter	Minimum Detected Concentration (mg/kg)	Location of Minimum Detected Concentration	Maximum Detected Concentration (mg/kg)	Location of Maximum Detected Concentration	Frequency of Detections	Range of Nondetect Detection Limits	Average Conc. (mg/kg)	Geometric Mean Conc. (mg/kg)	Median Conc. (mg/kg)	Standard Deviation (mg/kg)	Range of Background Concentrations	Important Bioaccumulative Compound [a]	Maximum Conc. Greater Than Background?	Constituent of Potential Concern?
Aluminum	610	SS-25	12500	SS-19	26 / 26	NA	4461	3311	4110	3298	543 - 6070	No	Yes	No
Arsenic	1.6	SS-24	160	SS-1	26 / 26	NA	26.4	10.4	6.7	39.2	ND(0.84) - 9.2	Yes	Yes	**YES**
Barium	1.9	SS-25	163	SS-2	26 / 26	NA	56.5	32.0	37.3	51.0	1.2 - 20.9	No	Yes	No
Beryllium	0.08	SS-24	1.4	SS-1	22 / 26	0.78 - 0.84	0.43	0.28	0.34	0.34	ND(0.079) - 0.2	No	Yes	No
Cadmium	0.25	SS-2	0.3	SS-1	3 / 26	0.093 - 0.28	0.09	0.07	0.06	0.07	ND(0.1) - ND(0.52)	Yes	Yes	**YES**
Calcium	101	SS-16	2180	SS-20	26 / 26	NA	684	492	528	560	53.3 - 3460	No	No	No
Chromium	1.2	SS-25	27.8	SS-19	26 / 26	NA	8.8	6.2	6.6	7.3	0.82 - 15.7	Yes	Yes	**YES**
Cobalt	0.68	SS-26	7.3	SS-1	24 / 26	0.41 - 0.47	2.9	1.9	2.1	2.2	ND(0.45) - 5.2	No	Yes	No
Copper	0.99	SS-16	17.7	SS-19	25 / 26	1 - 1	6.9	4.8	5.1	5.2	ND(0.97) - 13.1	Yes	Yes	**YES**
Iron	962	SS-25	27600	SS-2/SS-7	26 / 26	NA	11205	7376	7565	9073	191 - 16100	No	Yes	No
Lead	1.2	SS-16/SS-25	14.8	SS/19/SS-20	26 / 26	NA	4.9	3.8	4.1	3.8	0.73 - 12.4	Yes	Yes	**YES**
Magnesium	143	SS-11	5230	SS-20	26 / 26	NA	1162	735	742	1326	100 - 6270	No	No	No
Manganese	4.6	SS-24	116	SS-19	26 / 26	NA	36.5	24.7	27.5	30.3	1.9 - 271	No	No	No
Mercury	0.03	VARIOUS	0.2	SS-1	22 / 26	0.022 - 0.035	0.057	0.043	0.040	0.045	ND(0.022) - 0.03	Yes	Yes	**YES**
Nickel	0.73	SS-25	16.1	SS-19	26 / 26	NA	6.9	5.0	5.7	5.1	ND(0.63) - 11.1	Yes	Yes	**YES**
Potassium	95.6	SS-25	2690	SS-20	25 / 26	82.2 - 82.2	717	442	553	702	82.6 - 2200	No	Yes	No
Selenium	1.2	SS-12	4.9	SS-1	7 / 26	0.98 - 1.5	1.2	0.9	0.6	1.1	ND(1.1) - ND(5.5)	Yes	Yes	**YES**
Sodium	375	SS-11	15700	SS-20	25 / 26	111 - 111	2657	1543	1565	3715	489 - 31300	No	No	No
Thallium	2.8	SS-1	2.8	SS-1	1 / 26	1.1 - 3.3	0.8	0.8	0.7	0.5	ND(1.2) - ND(6.1)	No	Yes	No
Vanadium	1.7	SS-25	33.5	SS-1	26 / 26	NA	12.9	9.1	9.7	9.8	ND(1.2) - 19.6	No	Yes	No
Zinc	2.8	SS-25	71.9	SS-19	26 / 26	NA	19.5	13.2	15.1	18.8	ND(1.5) - 55.6	Yes	Yes	**YES**

[a] USEPA, 2000. Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment. Office of Water and Office of Solid Waste, Washington, DC. USEPA-823-R-00-001.
mg/kg – milligrams per kilogram.
ND – not detected above laboratory reporting limit.
NA – not applicable.

Table 5.1-2

Identification of Preliminary Constituents of Potential Concern in Offshore Sediment

Parameter	Minimum Detected Concentration (mg/kg)	Location of Minimum Detected Concentration	Maximum Detected Concentration (mg/kg)	Location of Maximum Detected Concentration	Frequency of Detection	Range of Nondetect Detection Limits	Average Conc. (mg/kg)	Geometric Mean Conc. (mg/kg)	Median Conc. (mg/kg)	Standard Deviation (mg/kg)	Range of Background Concentrations (mg/kg)	Important Bioaccumulative Compound [a]	Maximum Conc. Greater Than Background?	Constituent of Potential Concern?
Aluminum	1340	OS-23	18200	OS-1	26 / 26	NA	10165	8020	11700	5506	1700 - 6870	No	Yes	No
Arsenic	3.2	OS-18	37.4	OS-26	26 / 26	NA	16.6	14.0	14.7	9.5	ND(0.85) - 4.2	Yes	Yes	**YES**
Barium	7.6	OS-24	148	OS-12	26 / 26	NA	59.3	44.2	58.1	38.9	3.1 - 19.9	No	Yes	No
Beryllium	0.14	OS-23	1.9	OS-1	26 / 26	NA	0.94	0.74	1.08	0.51	0.11 - 0.32	No	Yes	No
Cadmium	0.13	OS-14	0.69	OS-1	14 / 26	0.11 - 0.27	0.27	0.19	0.18	0.20	ND(0.11) - ND(0.2)	Yes	Yes	**YES**
Calcium	236	OS-23	9100	OS-16	26 / 26	NA	2044	1539	2205	1676	259 - 1780	No	Yes	No
Chromium	4.2	OS24/OS-25	43.9	OS-1	26 / 26	NA	23.7	19.0	27.4	12.5	2.7 - 14.9	Yes	Yes	**YES**
Cobalt	0.85	OS-23	11.8	OS-1	26 / 26	NA	6.3	4.9	7.1	3.4	ND(0.45) - 4.2	No	Yes	No
Copper	2.4	OS24/OS-25	39.4	OS-1	26 / 26	NA	18.2	13.7	20.8	10.8	1.3 - 6.7	Yes	Yes	**YES**
Iron	3670	OS-24	34900	OS-1	26 / 26	NA	20678	16443	23550	10967	1400 - 12300	No	Yes	No
Lead	1.5	OS-23	25.3	OS-1	26 / 26	NA	13.1	10.6	16.3	6.7	2.1 - 10.7	Yes	Yes	**YES**
Magnesium	281	OS-23	7650	OS-1	26 / 26	NA	3757	2885	4520	2069	434 - 3080	No	Yes	No
Manganese	6.5	OS-23	212	OS-1	26 / 26	NA	103.3	79.4	121.5	56.3	9.5 - 106	No	Yes	No
Mercury	0.03	OS-24	0.26	OS-11	25 / 26	0.02 - 0.02	0.139	0.115	0.150	0.069	ND(0.019) - 0.06	Yes	Yes	**YES**
Nickel	2.2	OS-25	26	OS-1	26 / 26	NA	15.2	12.2	16.6	8.0	1.3 - 7.9	Yes	Yes	**YES**
Potassium	123	OS-23	3600	OS-1	26 / 26	NA	1889	1430	2340	1050	186 - 1450	No	Yes	No
Selenium	1.9	OS-2	3.4	OS-7/OS-8	7 / 26	1.1 - 2.9	1.5	1.2	1.2	0.9	ND(1.1) - ND(2.1)	Yes	Yes	**YES**
Sodium	1130	OS-26	14000	OS-19	26 / 26	NA	6846	5638	7680	3492	1500 - 9260	No	Yes	No
Thallium	NA	NA	NA	NA	0 / 26	0.65 - 1.65	1.1	1.1	1.2	0.3	ND(1.3) - ND(2.3)	No	No	No
Vanadium	4.7	OS-24	43.3	OS-1	26 / 26	NA	25.0	20.0	28.6	13.2	2.5 - 16.6	No	Yes	No
Zinc	4.7	OS-23	146	OS-1	26 / 26	NA	70.1	53.2	84.2	39.4	6.8 - 43.2	Yes	Yes	**YES**

[a] USEPA, 2000. Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment. Office of Water and Office of Solid Waste, Washington, DC. USEPA-823-R-00-001.
mg/kg – milligrams per kilogram.
ND – not detected above the laboratory reporting limit.
NA – not applicable.

5.1.2.2 COPCs in Surface Soil

Constituents of potential concern in surface soil of OU2 are identified by comparing the calculated exposure point concentration of each detected constituent to its URS for the protection of human health, assuming restricted use within a critical water resource area (DNREC, 1999). Additionally, the calculated exposure point concentration (EPC) for each constituent is compared to its corresponding background screening value (BSV). The BSVs for this assessment are the 95% upper tolerance level (UTL) referenced from the *Area 6 Remedial Investigation, Dover Air Force Base, Dover, Delaware* (Dames & Moore, 1994) as suggested for use and provided by DNREC-SIRB personnel and summarized in **Table 5.1-3**. **Table 5.1-4** presents the summary of the surface soil data collected as part of this OU2 RI, and shows arsenic as the only constituent that has been identified as a COPC in surface soil at OU2. The other detected constituents in surface soil collected from OU2 were less than their respective URS and/or BSV.

Table 5.1-3

Background Metals Concentrations in Soil

Constituent	Dover AFB Background				USGS Range Delaware (mg/kg)	95%-UCL Conc. Eastern U.S. (mg/kg)
	Minimum Conc. (mg/kg)	Maximum Conc. (mg/kg)	95%-UTL Conc. (mg/kg)			
Aluminum	16.8	18,100	23,855		15,000 - 30,000	272,000
Antimony	< 7.9	< 11.2	11.2	*	< 1	2.9
Arsenic	< 0.85	8.4	19.8		< 1 - 2.7	31
Barium	< 5.3	144	114		300 - 500	1,600
Beryllium	< 0.85	1.7	1.7	*	BDL	3.5
Cadmium	<0.68	0.84	0.84	*	--	--
Calcium	49.5	1,080	1,080	*	1,500 - 1,700	32,000
Chromium	3.7	21.5	45.7		10 - 12	223
Cobalt	< 1.9	6	6	*	5	39
Copper	< 3.2	7.8	7.8	*	3 - 7	102
Iron	585	16,300	72,875		5,000 - 10,000	115,000
Lead	1.2	11.7	33.1		10 - 20	53
Magnesium	86.9	2,020	10,166		500 - 1,000	26,000
Manganese	5.4	312	1,846		70 - 100	3,800
Mercury	< 0.11	0.16	0.16	*	0.03 - 0.05	0.05
Nickel	< 4.1	15	15	*	< 5 - 7	77
Potassium	< 288	1,280	2,250		--	27,000
Selenium	< 0.63	< 3.5	3.5	*	--	1.8
Silver	< 0.85	0.85	0.97	*	--	--
Sodium	< 27.9	170	618		2,000 - 5,000	52,000
Thallium	< 0.63	< 0.75	0.75	*	2.8 - 7	19.2
Vanadium	3.2	27.8	83.6		10 - 30	271
Zinc	3.4	34.1	177		17 - 29	178

mg/kg – milligrams per kilogram.

Table 5.1-4

Surface Soil Data Summary and Human Health COPC Identification

Chemical	Background Screening Value [c] (mg/kg)	Human Health URS[d] (mg/kg)	Maximum Detected Conc. (mg/kg)	Minimum Detected Conc. (mg/kg)	Mean Detected Conc. (mg/kg)	Detection Frequency	95%-UCL Conc.[a] (mg/kg)	Distribution [a]	Recommended Method [a]	Exposure Point Concentration [b] (mg/kg)	Constituent of Potential Concern?
Inorganics :											
ALUMINUM	2.39E+04	2.00E+05	1.97E+04	5.45E+03	1.28E+04	14 / 14	1.46E+04	Normal	Student's-t	1.46E+04	no (1,2)
ANTIMONY	1.12E+01	2.70E+01	1.20E+00	4.40E-01	8.83E-01	13 / 14	1.02E+00	Normal	KM (t)	1.02E+00	no (1,2)
ARSENIC	1.98E+01	3.00E+00	2.03E+02	2.70E+01	1.27E+02	14 / 14	1.50E+02	Normal	Student's-t	1.50E+02	**YES**
BARIUM	1.14E+02	1.40E+04	7.44E+02	7.41E+01	4.37E+02	14 / 14	5.26E+02	Normal	Student's-t	5.26E+02	no (1)
BERYLLIUM	1.70E+00	4.10E+02	4.50E+00	4.80E-01	2.71E+00	14 / 14	3.19E+00	Normal	Student's-t	3.19E+00	no (1)
CALCIUM	1.08E+03	NA	3.92E+03	5.65E+02	2.01E+03	14 / 14	2.42E+03	Normal	Student's-t	2.42E+03	no (3)
CHROMIUM, TOTAL	4.57E+01	3.50E+01	4.47E+01	7.90E+00	2.93E+01	14 / 14	3.41E+01	Normal	Student's-t	3.41E+01	no (1,2)
COBALT	6.00E+00	2.20E+01	1.77E+01	3.20E+00	1.27E+01	14 / 14	1.45E+01	Normal	Student's-t	1.45E+01	no (1)
COPPER	7.80E+00	8.20E+03	5.99E+01	1.22E+01	4.14E+01	14 / 14	4.77E+01	Normal	Student's-t	4.77E+01	no (1)
CYANIDE	NA	1.50E+01	2.90E-01	1.70E-01	3.08E-01	2 / 14	2.90E-01	Nonparametric	KM (% Bootstrap)	2.90E-01	no (1)
IRON	7.29E+04	6.10E+04	4.97E+04	1.08E+04	3.29E+04	14 / 14	3.78E+04	Normal	Student's-t	3.78E+04	no (1,2)
LEAD	3.31E+01	1.00E+03	3.57E+01	1.08E+01	2.22E+01	14 / 14	2.60E+01	Normal	Student's-t	2.60E+01	no (1,2)
MAGNESIUM	1.02E+04	NA	4.80E+03	3.93E+02	1.13E+03	14 / 14	2.50E+03	Nonparametric	Chebyshev (Mean,Sd)	2.50E+03	no (2,3)
MANGANESE	1.85E+03	4.10E+03	1.01E+02	2.22E+01	6.75E+01	14 / 14	7.64E+01	Normal	Student's-t	7.64E+01	no (1,2)
MERCURY	1.60E-01	1.00E+01	8.10E-01	1.10E-01	4.63E-01	14 / 14	5.58E-01	Normal	Student's-t	5.58E-01	no (1)
NICKEL	1.50E+01	6.50E+02	4.63E+01	7.20E+00	3.23E+01	14 / 14	3.71E+01	Normal	Student's-t	3.71E+01	no (1)
POTASSIUM	2.25E+03	NA	2.94E+03	5.60E+02	1.42E+03	14 / 14	1.70E+03	Normal	Student's-t	1.70E+03	no (2,3)
SELENIUM	3.50E+00	2.60E+01	7.20E+00	1.60E+00	3.68E+00	14 / 14	4.30E+00	Normal	Student's-t	4.30E+00	no (1)
SODIUM	6.18E+02	NA	4.63E+02	7.31E+01	1.75E+02	14 / 14	2.24E+01	Gamma	Approx Gamma	2.24E+01	no (2,3)
THALLIUM	7.50E-01	1.40E+01	2.20E+00	4.60E-01	1.34E+00	14 / 14	1.58E+00	Normal	Student's-t	1.58E+00	no (1)
VANADIUM	8.36E+01	1.40E+03	8.99E+01	1.66E+01	6.10E+01	14 / 14	7.10E+01	Normal	Student's-t	7.10E+01	no (1,2)
ZINC	1.77E+02	2.30E+03	8.50E+01	1.29E+01	5.32E+01	14 / 14	6.26E+01	Normal	Student's-t	6.26E+01	no (1,2)
General Chemistry :											
TOC	NA	NA	1.34E+05	1.66E+04	8.44E+04	14 / 14	--	--	--	--	no
PH	NA	NA	8.22E+00	4.62E+00	6.38E+00	14 / 14	--	--	--	--	no

[a] Nature of distribution and 95% UCL (Upper confidence limit) determined using ProUCL Version 4.00.05 (U.S. Environmental Protection Agency (USEPA), 2010b, Office of Research and Development, Las Vegas, Nevada, and Technology Support Center, Atlanta, GA, May, on line at http://www.epa.gov/esd/tsc/TSC_form.htm.
[b] Exposure point concentration (EPC) is equal to 95% UCL or maximum detected concentration, whichever is lower.
[c] Background Screening Values (BSV) are the 95% UTL concentrations defined in the *Area 6 Remedial Investigation, Dover Air Force Base, Dover, DE* (Dames & Moore, 1994).
[d] Delaware Uniform Risk-Based Remediation Standard for the protection of human health assuming restricted use in a critical water resource area.
Mg/kg – milligrams per kilogram
EPC - Exposure point concentration
KM - Kaplan-Meier Method.
ND - No data.
NA - Not applicable.
UCL - Upper confidence limit.
Rationale for exclusion as a COPC:
1 - Exposure point concentration is less than the Restricted Use Uniform Risk-Based Remediation Standard (URS)
2 - Exposure point concentration is less than the Background Screening Value (BSV)
3 - Essential macro-nutrient

5.1.3 Exposure Assessment

The objectives of the exposure assessment are to identify potentially exposed populations and quantify the type and magnitude of their exposure to COPCs that are present at OU2. In order to identify constituent sources, migration routes, exposure pathways, and potential receptors, a CSM is constructed. The human health CSM is presented as **Figure 5.1-2** and discussed below.

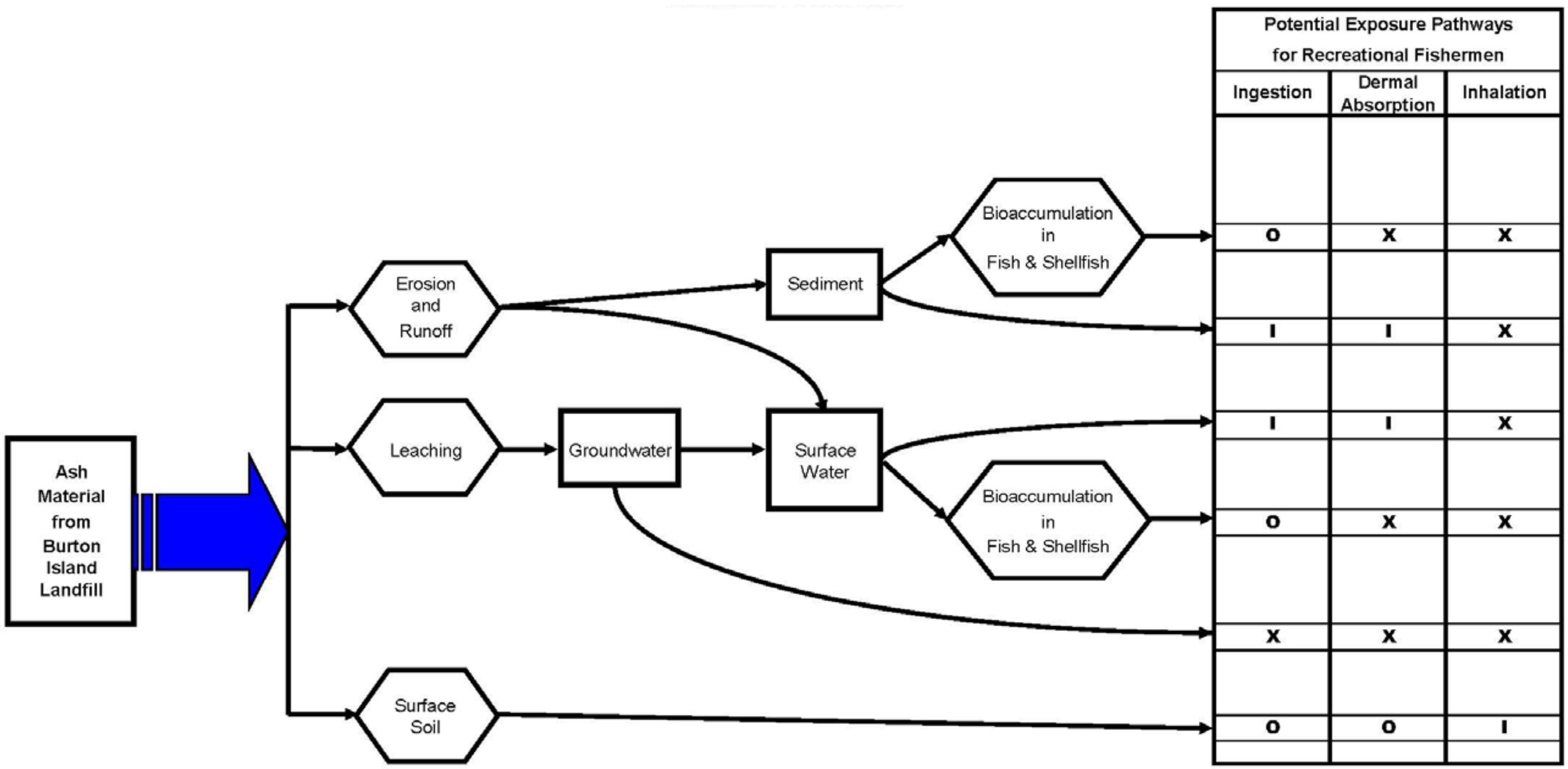
5.1.3.1 Potential Constituent Sources and Transport Mechanisms

Ash material from the Indian River Generating Station was historically placed on Burton Island from approximately 1957 until 1979. The ash material was held in place by berms constructed of fly ash. Since ash placement ceased in 1979 Burton Island has become re-vegetated with a variety of pioneer species including a number of grasses, sedges, bushes, and trees as described in Section 2.4 of this report. In addition to the natural vegetative succession that has taken place on the island over the years, the island's shorelines have been re-graded and hardened with stone revetment to reduce/eliminate shoreline erosion.

The major potential transport mechanism for OU2-related constituents to enter the environment is through leaching of the ash material into local groundwater and the transport of this leached material with local groundwater flow. This potential groundwater transport pathway formed the basis of the groundwater investigation described in Section 3.3. Both the Indian River and Island Creek are tidally influenced; therefore, during certain tidal stages there may be inflow of river/creek water to the groundwater beneath Burton Island. Per the groundwater CSM discussed in Section 3.3, groundwater discharges to surface water in Indian River and Island Creek during portions of each tidal cycle, and during different periods of the tidal cycle, surface water from Indian River and Island Creek infiltrates the groundwater beneath Burton Island. Therefore, the groundwater flow regime beneath Burton Island is a dynamic system that reverses flow direction depending on the tidal fluctuations of Indian River and Island Creek. Although the flow of impacted groundwater beneath Burton Island fluctuates depending on the tidal cycle, it does not impact potable water aquifers. Burton Island groundwater is fresh to brackish in quality and it is surrounded by saline surface water bodies. In situations where there is a water table aquifer underlying a land mass of limited extent, such as the Burton Island peninsula, terrestrial fresh water recharge is limited and the surrounding saline water envelope restricts the outward flow of fresh groundwater. Therefore, there are no complete human exposure pathways to potentially impacted groundwater at Burton Island.

Figure 5.1-2

Human Health Conceptual Site Model



O - Potentially complete exposure pathway
X - Incomplete exposure pathway
I - Potentially complete, but insignificant exposure pathway

Another potential transport mechanism on Burton Island is the over-land flow of surface material via surface runoff during storm events. Potential migration mechanisms for constituents in impacted media include soil transport via over-land flow, soil deposition, adsorption/desorption, soil re-suspension, transport and dispersion via fugitive dust, uptake by terrestrial plants, bioaccumulation into terrestrial organisms, and trophic transfer via the food web.

Although fugitive dust generation and transport via air dispersion is a potential transport mechanism for constituents in surface soil at Burton Island, this transport mechanism is considered to be negligible, based on the results of the air dispersion modeling analysis described in Section 4. An estimation of the potential for fugitive dust generation and air dispersion is presented in Section 4 of this report. The results of this fugitive dust generation and dispersion analysis show that concentrations of PM_{10} and $PM_{2.5}$ are expected to be less than their respective NAAQS at the closest sensitive receptor locations assuming Burton Island remains vegetated at its current level. Based on this fugitive dust generation and dispersion analysis, the inhalation exposure pathway is considered to be negligible.

If site-related constituents enter the surrounding water bodies, either by leaching to groundwater and subsequent discharge to surface water or erosion and runoff into the intertidal areas, they may be bioaccumulated by fish and/or shellfish that utilize the surrounding water bodies for feeding and breeding habitat. Fish, shellfish, or other organisms living in Indian River or Island Creek in the vicinity of Burton Island may bioaccumulate site-related constituents. Although many metals show a potential for bioaccumulation, they do not result in biomagnification (USEPA, 2000a). Exceptions to this are arsenic and methyl mercury, which have shown the potential to biomagnify (Suedel, 1994). Of the fifteen metals that are addressed in the *Final Water Quality Guidance for the Great Lakes System* (USEPA, 1995), only methyl mercury is listed as a bioaccumulative constituent of concern. The potential for bioaccumulation is site- and species-specific. Therefore, the inclusion of a number of inorganic constituents as potential COPCs in this assessment is conservative. Aquatic plants may accumulate constituents via uptake from surface water and sediment. Plants are more prone to accumulate metals than high molecular weight organics (Travis and Arms, 1988; Baes, et al., 1984; USEPA, 1999); therefore, uptake of metals by plants is considered a viable migration pathway.

5.1.3.2 Potentially Exposed Populations

Burton Island is private property owned by IRP and access to the site is restricted to site personnel. Also, there are no ongoing routine operations at the Ash Site. Plant personnel may access Burton Island occasionally for maintenance activities, but these activities are not routine and are sporadic. Additionally, the only authorized entrance is through a locked gate and potential exposures by plant personnel would be mitigated by facility health and safety procedures designed to minimize and/or eliminate such exposures. Therefore, exposures to plant personnel are expected to be minimal. Likewise, potential exposure to ash material by construction workers on Burton Island would be mitigated by facility health and safety procedures designed to minimize and/or eliminate exposures to hazardous materials. Trespassers could potentially illegally access Burton Island and be exposed to ash material; however, these potential exposures are expected to be sporadic and minimal in nature due to security measures at the Indian River Generating Station. Therefore, any potential human exposure to ash material in the former ash management area itself is expected to be sporadic and minimal in nature.

There are no potable water wells on Burton Island and groundwater beneath Burton Island has been shown to be isolated from potable water sources (Section 3.3); therefore, there are no human receptor populations for groundwater. Fugitive dust generation and dispersion from OU2 has been shown to be minimal (Section 4.0). The only potential human exposure to ash material that could be considered somewhat routine would be recreational boaters/fishermen who utilize Indian River and/or Island Creek as a fishing ground. Recreational fishermen could be exposed to ash material through bioaccumulation into fish and shellfish with subsequent consumption by these recreational fishermen. Based on the current and expected future land uses of the Ash Site, the only potentially exposed population subject to further evaluation is recreational fishermen and their families, as summarized in **Table 5.1-5**.

Table 5.1-5

Potential Receptors for Human Health Risk Assessment

Potential Receptors	Quantitatively Assessed? / Rationale
On-site resident	No, no on-site residents
Off-site resident	No, no complete exposure pathways
On-site plant personnel	No, insignificant potential exposures mitigated by plant H&S requirements
On-site construction worker	No, insignificant potential exposures mitigated by plant H&S requirements
Trespasser / fishermen	Yes, potentially complete exposure pathways

5.1.3.3 Identification of Exposure Pathways

The recreational fishermen receptor population could potentially be exposed to site-related constituents through the consumption of recreationally caught fish and/or shellfish. Since these same recreational fishermen could potentially be exposed to site-related constituents via trespassing on Burton Island with subsequent incidental ingestion and dermal absorption of surface soil, DNREC requested that this pathway be included. No other exposure pathways (i.e. ingestion of surface water or sediment) are complete for this exposure scenario. Therefore, the only exposure pathways that are quantitatively assessed in the human health risk assessment for the Ash Site are the assessment of the recreational fishermen receptor population for the following:

- ingestion of recreationally caught fish/shellfish;
- incidental ingestion of surface soil while trespassing; and
- dermal absorption of surface soil while trespassing.

It is important to note that ingestion of recreationally caught fish/shellfish is an exposure pathway that is associated with OU1, and incidental ingestion of surface soil and dermal absorption of surface soil are exposure pathways associated with OU2. Although fish/shellfish ingestion was assessed in conjunction with OU1 and OU3 and it was determined that the "level of contamination present at Burton Island did not pose an undue health risk to an adult or child who may be exposed to the contaminants from eating fish from the local waters" (DNREC, 2008), this potential exposure pathway was incorporated into the assessment of OU2 in order to estimate total cumulative risks/hazards experienced by the recreational fisherman receptor population.

5.1.3.4 Exposure Pathway Dosage Estimates

In order to quantify constituent exposures, environmental medium-specific exposure algorithms are developed for each complete exposure pathway. These exposure algorithms are used to estimate the chronic daily intake (CDI) of COPCs by a receptor population (i.e., recreational fishermen).

For each exposure activity (i.e. consumption of recreationally caught fish), the CDI, expressed as mg/kg/day, is an averaged daily dose of a COPC ingested or absorbed by a receptor. The averaged dose received by a receptor is the critical point estimate for determining the extent of health risk/hazard associated with exposure to each COPC. The exposure parameters that influence receptor intake or absorption of COPCs, including exposure duration and frequency, can and do vary in the exposure algorithms used to estimate the CDI by different exposure routes to the same medium. For each identified pathway, a reasonable maximum exposure (RME) scenario is developed. The exposure parameters used in the RME assessments are upper-bound (90 to 95th percentile) point estimates for each parameter and present a maximal conservative exposure assessment. The exposure parameters that are used to quantify exposures in the human health risk assessment for OU2 are presented below.

Fish/Shellfish Ingestion Algorithm. The CDI of constituents due to ingestion of recreationally caught fish and shellfish is calculated by the following formula:

$$CDI_{fish} = \frac{C_{fish} \times IR_{fish} \times ABS \times EF \times ED}{BW \times AT}$$

where:

CDI_{fish}	=	Chronic daily intake of fish/shellfish (mg/kg-day);
C_{fish}	=	Constituent concentration in fish (mg/kg);
IR_{fish}	=	Ingestion rate of fish (kg/day);
ABS	=	Absorption factor (1.0, unitless);
EF	=	Exposure frequency (days/yr);
ED	=	Exposure duration (years);
BW	=	Body weight (kg); and
AT	=	Averaging time (days).

Exposure parameters for both adults and children that are used to quantify exposures via fish/shellfish ingestion in this assessment are those presented in *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, 3rd Edition* (USEPA, 2000b). The adult fish/shellfish ingestion rate also corresponds to the site-specific seafood consumption rate for recreational anglers and their households in the Delaware Estuary as reported by KCA (1994). The exposure parameters used in the formula above are summarized in **Table 5.1-6**.

Table 5.1-6

Exposure Parameters for Fish/Shellfish Ingestion

Exposure Parameter	RME value
Fish ingestion rate (adult)	0.0175 kg/day
Fish ingestion rate (child)	0.0065 kg/day
GI absorption factor	1.0 (unitless)
Exposure frequency	350 days/year
Exposure duration (adult)	30 years
Exposure duration (child)	3 years
Body weight (adult)	70 kg
Body weight (child)	17 kg
Carcinogenic averaging time (adult)	25,550 days
Carcinogenic averaging time (child)	25,550 days
Non-carcinogenic averaging time (adult)	10,950 days
Non-carcinogenic averaging time (child)	1,095 days

RME – reasonable maximum exposure.
kg/day – kilograms per day.
kg - kilogram

Soil Ingestion Algorithm. The CDI of constituents due to incidental ingestion of surface soil is calculated by the following formula:

$$CDI_{soil-ing} = \frac{C_{soil} \times IR_{soil} \times ABS \times EF \times ED \times CF}{BW \times AT}$$

where:

$CDI_{soil\text{-}ing}$ = Chronic daily intake of surface soil from incidental ingestion (mg/kg-day);
C_{soil} = Constituent exposure point concentration in surface soil (mg/kg);
IR_{soil} = Ingestion rate of soil (kg/day);
ABS = Absorption factor (1.0, unitless);
EF = Exposure frequency (days/yr);
ED = Exposure duration (years);
CF = Conversion factor (10^{-6} kg/mg);
BW = Body weight (kg); and
AT = Averaging time (days).

Soil Dermal Absorption Algorithm. The CDI of constituents due to dermal absorption of surface soil is calculated by the following formula:

$$CDI_{soil-abs} = \frac{C_{soil} \times ABS \times SA \times AF \times EF \times ED \times CF}{BW \times AT}$$

where:

$CDI_{soil\text{-}abs}$	=	Chronic daily intake of surface soil from dermal absorption (mg/kg-day);
C_{soil}	=	Constituent exposure point concentration in surface soil (mg/kg);
SA	=	Surface area of exposed skin (cm^2/event);
AF	=	Soil adherence factor (mg/cm^2);
ABS	=	Dermal absorption factor (0.01, unitless);
EF	=	Exposure frequency (events/yr);
ED	=	Exposure duration (years);
CF	=	Conversion factor (10^{-6} kg/mg);
BW	=	Body weight (kg); and
AT	=	Averaging time (days).

The soil ingestion rates, exposure frequency, exposure duration, body weights and averaging times are default exposure parameters presented in the *Hazardous Substance Cleanup Act Guidance Manual* (DNREC, 1994). The soil adherence factor (0.11 mg/cm^2) used in this assessment is the average for the hands, arms, legs, face, and feet for gardeners presented in the USEPA's *Exposure Factors Handbook* (1997). The surface area of exposed skin for adults (5,800 cm^2) is the upper percentile for outdoor soil contact presented in USEPA (1997a). The surface area of exposed skin for children (5,028 cm^2) is the 90^{th} percentile of surface area of the head, arms, hands, legs, and feet for children aged 2 – 6 years (USEPA, 1997a). The exposure parameters used in the formula above are summarized in **Table 5.1-7**.

Table 5.1-7

Exposure Parameters for Surface Soil Ingestion and Dermal Absorption

Exposure Parameter	RME value
Soil ingestion rate (adult)	100 mg/day
Soil ingestion rate (child)	200 mg/day
GI absorption factor	1.0 (unitless)
Exposure frequency	78 days/year
Exposure duration (adult and child)	6 years
Soil Adherence Factor	0.11 mg/cm^2
Body weight (adult)	70 kg
Body weight (child)	17 kg
Surface Area of Exposed Skin (adult)	5,800 cm^2
Surface Area of Exposed Skin (child)	5,028 cm^2
Dermal Absorption Factor	0.001 (unitless)
Carcinogenic averaging time (adult and child)	25,550 days
Non-carcinogenic averaging time (adult and child)	2,190 days

RME – reasonable maximum exposure.
mg/day – milligrams per day.
mg/cm^2 - milligram per square centimeter.
kg - kilogram
cm^2 - square centimeter.

Exposure Point Concentrations. For quantitative human health risk assessments, the concentration term (exposure point concentration) in the exposure equations is an estimate of the arithmetic average concentration for a constituent based on a set of sampling results. Because of the uncertainty associated with estimating the true average concentration at a site, the 95 percent upper confidence limit (UCL) of the arithmetic mean is often used for this variable. The 95 percent UCL provides reasonable confidence that the true site average concentration will not be underestimated and is routinely used as the EPC in the exposure algorithm.

Statistical analyses were performed to verify the distribution of constituents in surface soil and sediment at the Ash Site. The first step was to determine the appropriate statistical distribution (i.e., normal, log-normal, or other) that the data represented. Based on the distribution of the sampling results, several different equations can be used to estimate the UCL of the data. For normal and log-normal distributions, the UCL is calculated according to the following equations.

For normal distributions:

$$UCL \quad = \quad x + t\left(\frac{s}{\sqrt{n}} \right)$$

where:

UCL = upper confidence limit$x$

= mean of the un-transformed data$s$

= standard deviation of the un-transformed data$t$

= Student-t statistic$n$

= number of samples.

For log-normal distributions:

$$UCL \quad = \quad e^{\left(x + 0.5s^2 + sH / \sqrt{n-1} \right)}$$

where:

UCL = upper confidence limit e

= base of the natural log, equal to 2.718;

x = mean of the transformed data$s$

= standard deviation of the transformed data$H$

= H-statistic$n$

= number of samples.

USEPA's Pro-UCL version 4.00.05 (USEPA, 2010b) was used to estimate the 95 percent UCLs for sediment and surface soil at OU2. The 95 percent UCL is calculated for each of the COPCs and is used as a conservative estimate of the true average concentration for that COPC. This calculated UCL value is used as the EPC in the exposure algorithm. If the 95 percent UCL concentration is greater than the maximum detected concentration, then the maximum detected constituent concentration is used to represent the exposure point concentration of the particular COPC. In the derivation of the above statistics, one-half of the analytical detection limit is used for all samples with non-detectable concentrations of a given constituent. Summaries of the exposure point concentrations for each of the COPCs in surface soil and sediment and the methodology for computing the UCL are presented in **Tables 5.1-4** and **5.1-8**, respectively.

In the process of identifying preliminary COPCs in shoreline and offshore sediment samples (Section 5.1.2) it became apparent that the same constituents were identified as preliminary COPCs in shoreline and offshore sediment samples. The detected concentrations in these two

Table 5.1-8

Human Health Exposure Point Concentrations in Shoreline and Offshore Sediment Samples

Parameter	Minimum Detected Conc. (mg/kg)	Location Of Minimum	Maximum Detected Conc. (mg/kg)	Location Of Maximum	Frequency Of Detections	Range of Nondetect Detection Limits	Average Conc. (mg/kg)	Geometric Mean Conc. (mg/kg)	Median Conc. (mg/kg)	Standard Deviation (mg/kg)	Distribution	UCL_{norm} (mg/kg)	UCL_{log} (mg/kg)	$UCL_{Jackknife}$ (mg/kg)	$UC_{Chebychev}$ (mg/kg)	Range of Background Concentrations	EPC (mg/kg)	Basis for EPC
Aluminum	610	SS-25	18200	OS-1	52 / 52	--	7313	5153	5830	5337	Both	8553	10578	9430	10539	543 - 6870	8553	Normal
Arsenic *	1.6	SS-24	160	SS-1	52 / 52	--	21.5	12.0	13.0	28.6	Log	28.2	31.1	29.9	38.8	ND - 9.2	31.1	Log
Barium	1.9	SS-25	163	SS-2	52 / 52	--	57.9	37.6	40.0	44.9	Both	68.4	98.4	75.1	85.1	1.2 - 20.9	68.4	Normal
Beryllium	0.08	SS-24	1.9	OS-1	48 / 52	0.072 – 0.083	0.68	0.45	0.66	0.50	Both	0.80	1.14	0.88	0.98	ND - 0.32	0.80	Normal
Cadmium *	0.13	OS-14	0.69	OS-1	17 / 52	0.093 – 0.27	0.18	0.12	0.08	0.18	Neither	0.22	0.23	0.24	0.29	ND - ND	0.29	Chebychev
Calcium	101	SS-16	9100	OS-16	52 / 52	--	1364	870	932	1415	Log	1690	2030	1823	2219	53.3 - 3460	2030	Log
Chromium *	1.2	SS-25	43.9	OS-1	52 / 52	--	16.2	10.9	11.4	12.6	Both	19.2	24.6	21	23.9	0.82 - 15.7	19.2	Normal
Cobalt	0.6	SS-16	11.8	OS-1	50 / 52	0.41 – 0.47	4.6	3.1	4.4	3.3	Both	5.3	7.3	5.9	6.6	ND - 5.2	5.3	Normal
Copper *	0.99	SS-16	39.4	OS-1	51 / 52	1 – 1	12.5	8.1	9.6	10.1	Both	14.9	20	16.3	18.7	ND - 13.1	14.9	Normal
Iron	962	SS-25	34900	OS-1	52 / 52	--	15942	11013	17700	11054	Both	18510	24790	20480	22623	191 - 16100	18510	Normal
Lead *	1.2	SS-16 SS-25	25.3	OS-1	52 / 52	--	9.0	6.4	6.5	6.8	Both	10.6	12.6	11.6	13.1	0.73 - 12.4	10.6	Normal
Magnesium	143	SS-11	7650	OS-1	52 / 52	--	2460	1456	1610	2162	Both	2960	4120	3225	3767	100 - 6270	2960	Normal
Manganese	4.6	SS-24	212	OS-1	52 / 52	--	69.9	44.3	53.5	56.1	Both	83	116	90.9	103.8	1.9 - 271	83	Normal
Mercury *	0.03	VARIOUS	0.26	OS-11	47 / 52	0.02 – 0.035	0.098	0.070	0.090	0.071	Both	0.11	0.14	0.13	0.141	ND - 0.06	0.11	Normal
Nickel *	0.73	SS-25	26	OS-1	52 / 52	--	11.1	7.8	9.6	7.8	Both	12.9	16.5	14.2	15.8	ND - 11.1	12.9	Normal
Potassium	91.9	SS-13	3600	OS-1	51 / 52	82.2 - 82.2	1303	795	908	1064	Both	1550	2310	1696	1946	82.6 - 2200	1550	Normal
Selenium *	1.2	SS-12	4.9	SS-1	14 / 52	0.98 – 3	1.3	1.1	1.1	1.0	Log	1.57	1.57	1.72	1.9	ND - ND	1.6	Log
Sodium	375	SS-11	15700	SS-20	51 / 52	111 – 111	4751	2950	2415	4149	Log	5720	8170	6225	7259	489 - 31300	8170	Log
Thallium	2.8	SS-1	2.8	SS-1	1 / 52	1.1 – 3.3	1.0	0.9	0.8	0.4	NA	NA	NA	1.2	1.3	ND - ND	1.3	Chebychev
Vanadium	1.7	SS-25	43.3	OS-1	52 / 52	--	19.0	13.5	17.4	13.1	Both	22	27.7	24.3	26.8	ND - 19.6	22	Normal
Zinc *	2.8	SS-25	146	OS-1	52 / 52	--	44.8	26.6	25.3	39.8	Both	54	74.6	58.8	68.9	ND - 55.6	54	Normal

* - Shading and asterisk indicates constituents that have been identified as human health COPCs.

mg/kg – milligram per kilogram.

EPC – exposure point concentration.

UCL – upper confidence limit.

groups of samples were also similar (**Tables 5.1-1** and **5.1-2**). Additionally, fish and crabs (shellfish) are not sessile organisms and sometimes travel great distances to find adequate food sources, mating grounds, and rearing grounds for their young. By traveling significant distances, they effectively integrate exposures over a large home range and, therefore, a large range of COPC concentrations. In order to take into account the non-sessile habitats of these animals, the data sets for the shoreline and offshore sediment samples were combined to form a single dataset which characterizes the sediment in the near-shore environment surrounding Burton Island.

The estimated EPCs for the sediment COPCs are presented in **Table 5.1-8**. Although fish and crabs caught in the vicinity of Burton Island may be exposed to, and accumulate, constituents from other areas of the Delaware coastal bays and even offshore locations along the Atlantic coast, the focus of this human health risk assessment is OU2 of the Ash Site. As such, it is conservatively assumed for this assessment that the fish and crabs consumed by the recreational fisherman receptor population derive their tissue burdens of COPCs exclusively from the sediment surrounding the Ash Site.

Fish and shellfish tissue concentrations of COPCs are estimated by assuming the accumulation of sediment COPCs in biota tissues takes place as a linear relationship between sediment concentration and tissue concentration of COPCs. This linear relationship is commonly known as the sediment-to-biota bioaccumulation factor (BAF). In order to estimate fish and shellfish tissue concentration of COPCs, the EPC of each sediment COPC is multiplied by the constituent-specific sediment-to-biota BAF in the following manner:

$$C_{biota} = C_{sed} \times BAF_{sed-to-biota}$$

where:

C_{biota}	=	COPC concentration in biota tissue (mg/kg);
C_{sed}	=	COPC concentration in sediment (mg/kg); and
$BAF_{sed\text{-}to\text{-}biota}$	=	sediment-to-biota bioaccumulation factor.

Per USEPA guidance (USEPA, 2000b), most of the arsenic present in fish and shellfish tissue is organic arsenic, primarily pentavalent arsenobetaine, which has been shown in numerous studies to be metabolically inert and nontoxic (Brown, et al., 1990; Cannon, et al., 1983; Charbonneau, et al., 1978; Bos, et al., 1985; Kaise, et al., 1985; Luten, et al., 1982; Sabbioni, et al., 1991; Siewicki, 1981; Bryce, et al., 1982; Vahter, et al., 1983; Yamauchi, et al., 1986). Inorganic arsenic, which is of concern for human health effects (ATSDR, 2000; WHO, 1989), is generally found in seafood at concentrations ranging from < 1 to 20 percent of the total arsenic concentration (Edmonds and Francesconi, 1993; Nraigu and Simmons, 1990). Based on data collected as part of the study entitled *Total and Inorganic Arsenic in Mid-Atlantic Marine Fish and Shellfish and Implications for Fish Advisories* (Greene and Crecelius, 2006), approximately 0.7% to 1.7% of the total arsenic detected in fish and shellfish is in the inorganic form. Therefore, for this assessment, the mean value (1.2%) was used to apportion the inorganic arsenic concentration from the total arsenic concentration.

The sediment-to-biota BAFs used to estimate the COPC concentrations in fish and shellfish are summarized below in **Table 5.1-9**, as are the estimated fish/shellfish tissue concentrations.

Table 5.1-9
Sediment-to-Biota BAFs and Estimated Fish/Shellfish Tissue Concentrations

Sediment COPC	Sediment EPC (mg/kg)	$BAF_{sed\text{-}to\text{-}biota}$	Fish/Shellfish EPC (mg/kg)
Arsenic	31.1	0.9	0.34
Cadmium	0.29	3.4	0.99
Chromium	19.2	0.39	7.49
Copper	14.9	0.3	4.47
Lead	10.6	0.63	6.68
Mercury	0.11	0.48 [(a)]	0.053
Nickel	12.9	0.9	11.6
Selenium	1.6	0.9	1.44
Zinc	54	0.57	30.8

Note : Sediment-to-invertebrate BAF for methyl mercury.
mg/kg – milligrams per kilogram
EPC – exposure point concentration
BAF – bioaccumulation factor
COPC – constituent of potential concern

The sediment-to-biota BAFs used in this assessment are the sediment-to-benthic invertebrate BAFs presented in USEPA's *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (1999). These BAFs are most appropriate for use in estimating COPC concentrations in shellfish tissues (i.e. crabs); however, there are no available sediment-to-fish BAFs for the inorganic sediment COPCs. Therefore, the sediment-to-benthic invertebrate BAFs are used to estimate COPC tissue concentrations for both shellfish and fish. These sediment-to-biota BAFs are expected to be conservative since they are applicable to invertebrates that live either buried beneath the sediment or on the surface of the sediment. As such, the benthic invertebrates are in close contact with the sediment continuously. Other organisms (i.e. fish) that would only contact the sediment periodically, would be expected to exhibit lower accumulation rates (e.g. lower BAFs). The estimated fish/shellfish tissue concentrations are used as the EPC in the exposure algorithm described above in order to estimate exposures to COPCs from ingestion of recreationally caught fish/shellfish.

It is important to note that actual measured fish/shellfish tissue concentrations from previous studies (Greene and Crecelius, 2006) were less than those estimated using the methodology described above. For instance, total arsenic measured in summer flounder (*Paralicthys dentatus*), Atlantic croaker (*Micropogonias undulates*), hard clam (*Mercenaria mercenaria*), and striped bass (*Marone saxatilis*) ranged from 3.33 mg/kg-wet weight to 0.36 mg/kg-wet weight. The estimated arsenic concentration in fish/shellfish using the sediment-to-benthic invertebrate BAFs described above, resulted in a total arsenic concentration of 28 mg/kg, which is significantly higher than measured arsenic concentrations in fish/shellfish in the Delaware coastal bays. In other words, the modeled arsenic concentrations in fish/shellfish tissue used in this assessment are significantly higher than the measured arsenic concentrations in fish/shellfish tissue that actually occur in the Delaware coastal bays. Thus, this methodology results in a conservative estimate of COPC concentrations in fish/shellfish and likely over-estimates COPC exposures.

It should also be noted that the DNREC Division of Water Resources currently prohibits the harvesting of shellfish from the waters surrounding Burton Island and other areas of the Delaware Inland Bays due to the potential for bacterial pollution not related to the Ash Site or the Indian River Generating Plant. This shellfish harvesting prohibition effectively eliminates legal human exposures to shellfish from these prohibited areas (including the area surrounding Burton Island). There are no fish consumption advisories related to metals in the Delaware Inland Bays.

5.1.4 Toxicity Assessment

The toxicity assessment weighs the available evidence regarding the potential for particular constituents to cause adverse effects in exposed individuals (receptors) and provides, where possible, an estimate of the relationship between the extent of exposure to a constituent and the increased likelihood and/or severity of induced adverse health effects. Two broad categories of chemically-induced disease states are evaluated in the toxicity assessment of each identified constituent: carcinogenic effects; and non-carcinogenic effects.

As the exposure assessment attempts to define the chronic lifetime dosage of COPCs received by an individual in a given scenario, the toxicity assessment links adverse effects associated with exposure to the particular COPC. Establishing an association between exposure to a constituent with possible adverse effects is the major tenet of toxicology. The dose received determines the magnitude of any anticipated adverse effects related to the constituent's inherent toxicity.

Toxicity values are used in risk characterization to quantify the probability of observing cancer and non-cancer effects in a potentially exposed population. Two types of toxicity values are used to express a COPC's dose-response-effect relationship:

- A slope factor (SF) for estimating the likelihood of carcinogenic effects; and
- A reference dose (RfD) or reference concentration (RfC) for estimating possible non-carcinogenic effects.

In general, SF and RfD values, expressed in the units of $(mg/kg\text{-}day)^{-1}$ and mg/kg-day, respectively, are derived from long-term animal studies and incorporate uncertainty factors to compensate for extrapolation of observed adverse effects in laboratory animals to estimate possible adverse effects in humans. If adequate human data from epidemiological studies are available, these data are used to reduce uncertainty in deriving toxicity values.

5.1.4.1 Toxicity Assessment for Carcinogenic Effects

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e., incremental or excess individual lifetime cancer risk). Based on the extent to which a constituent has been shown to be a carcinogen in animal studies, in humans, or in both, the agent is given a provisional weight-of-evidence classification. USEPA's current classification of the overall weight of evidence has the following five categories:

- **Group A:** Human Carcinogen - Sufficient evidence from epidemiological studies substantiated by causal association between exposure and carcinogenicity.

- **Group B1:** Probable Human Carcinogen - Limited evidence of carcinogenicity in humans from available epidemiological data.

- **Group B2:** Probable Human Carcinogen - Sufficient evidence of carcinogenicity in animals, but inadequate or no evidence in humans.

- **Group C:** Possible Human Carcinogen - Limited evidence of carcinogenicity in animals.

- **Group D:** Not Classified - Inadequate evidence of carcinogenicity in animals to support classification.

- **Group E:** Not a Human Carcinogen - No evidence of carcinogenicity in at least two adequate animal tests in different species or in both epidemiological and animal studies.

Based on the evidence that a constituent is a known or probable human carcinogen, a toxicity value that defines a quantitative relationship between dose and response (i.e., cancer slope factor) is calculated by the USEPA. A SF converts estimated daily intakes averaged over a lifetime of exposure directly to incremental risk of an individual developing cancer. The carcinogenic slope factors for the COPCs in surface soil and sediment are presented below in **Table 5.1-10**.

Table 5.1-10
Toxicity Values for Surface Soil and Sediment COPCs

Sediment COPC	**Carcinogenic Slope Factor** $(mg/kg/day)^{-1}$	**Non-Carcinogenic Reference Dose** (mg/kg/day)
Arsenic	1.5 E+00	3.0E-04
Cadmium	NA	1.0E-03
Chromium (+3)	NA	1.5E+00
Chromium (+6)	NA	3.0E-03
Copper	NA	4.0E-02 (a)
Lead	NA	NA
Mercury (elemental)	NA	NA
Methyl Mercury	NA	1.0E-04
Nickel	NA	2.0E-02
Selenium	NA	5.0E-03
Zinc	NA	3.0E-01

Notes: All of the toxicity values referenced above are from USEPA's IRIS database (2010).
(a) Referenced from Health Effects Assessment Summary Tables (HEAST) (1997).
mg/kg – milligram per kilogram.
COPC – constituent of potential concern.
NA – not applicable.

5.1.4.2 Toxicity Assessment of Non-Carcinogenic Effects

A chronic RfD is an estimate of the daily exposure to a human population, including sensitive subpopulations, that is unlikely to cause an increased incidence of deleterious health effects during a lifetime of exposure. Chronic RfD values are specifically developed to be protective for long-term exposure to a constituent.

Two toxicity assessment terms are used to characterize low dose exposure effects. The no-observed-adverse-effect-level (NOAEL) is an exposure level where there are no statistically or biologically significant increases in the frequency or severity of adverse effects in the exposed population. The lowest-observed-adverse-effect-level (LOAEL) is the lowest exposure dose in a dose-response experiment at which there are statistically or biologically significant increases in severity or frequency of adverse effects in the exposed population.

In arriving at RfD toxicity values, the NOAEL or LOAEL is divided by additional factors to account for uncertainties in extrapolation from subchronic to chronic exposures and from uncertain species-to-species toxicity relationships. These uncertainty factors can range from 1 to 10,000.

The toxicity assessment component of this human health risk assessment is entirely dependent upon the use of USEPA-derived toxicity values referenced from the following sources:

- Integrated Risk Information System (IRIS, 2010), an on-line database maintained by the USEPA; and
- Health Effects Assessment Summary Tables (HEAST, 1997), published annually by the USEPA.

The non-carcinogenic toxicity data for the identified COPCs are presented in **Table 5.1-10**.

The non-carcinogenic effects and target organs/systems for the surface soil and sediment COPCs are the following:

- Arsenic: hyperpigmentation
- Cadmium: significant proteinuria
- Chromium: no observed adverse effects
- Copper: gastrointestinal irritation
- Mercury (methyl): developmental neuropsychological impairment
- Nickel: decreased body and organ weight
- Selenium: clinical selenosis
- Zinc: decrease in erythrocyte Cu, Z- superoxide dismutase (ESOD) activity

As the list above indicates, none of the soil or sediment COPCs act on the same target organ or system; therefore, their non-carcinogenic effects are not additive.

An important consideration with regard to arsenic toxicity is the fact that in seafood, arsenic can exist in many forms, including the inorganic species arsenite (As III), and arsenate (As V), as well as the organic species arsenobetaine, arsenocholine, monomethylarsonic acid (MMA), dimethylarsinic acid (DMA), arsenosugars, and arsenolipids (Cullen and Reimer, 1989; Chew, 1996). Current guidance suggests the inorganic species arsenite and arsenate are the most toxic forms of arsenic and only these forms of arsenic should be used to estimate exposure and subsequent risk from seafood consumption. The various organic arsenic compounds in fish and shellfish are considered to be metabolically inert and relatively non-toxic (ATSDR, 2000). Because the sediment samples were analyzed for total arsenic and no biota samples were collected for this assessment, it is appropriate to apportion the total estimated tissue concentrations of arsenic into organic and inorganic fractions. Based on data collected as part of the study entitled *Total and Inorganic Arsenic in Mid-Atlantic Marine Fish and Shellfish and Implications for Fish Advisories* (Greene and Crecelius, 2006), approximately 0.7% to 1.7% of the total arsenic detected in fish and shellfish is in the inorganic form. Therefore, for this assessment, the mean value (1.2%) was used to apportion the inorganic arsenic concentration from the measured total arsenic concentration.

Although IRIS (2010) considers lead as "reasonably anticipated to be a human carcinogen", no CSF or RfD is provided. Quantifying lead's cancer risk involves many uncertainties, some of which may be unique to lead. Age, health, nutritional state, body burden, and exposure duration influence the absorption, release, and excretion of lead. In addition, current knowledge of lead pharmacokinetics indicates that an estimate derived by standard procedures would not truly describe the potential risk. Thus, the Carcinogen Assessment Group recommends that a numerical estimate not be used.

USEPA considered providing an RfD for inorganic lead in 1985, and concluded that it was inappropriate to develop an RfD. Current knowledge of lead pharmacokinetics indicates that risk values derived by standard procedures would not truly indicate the potential risk, because of the difficulty in accounting for pre-existing body burdens of lead. Lead bioaccumulates in the body, primarily in the skeleton. Lead body burdens vary significantly with age, health status, nutritional state, maternal body burden during gestation and lactation, etc. For this reason, and because of the continued apparent lack of threshold, it is still inappropriate to develop reference values for lead.

Based on the fact that USEPA provides neither a carcinogenic SF nor a non-cancer RfD for lead, it is not possible to quantify health risks/hazards from exposures to lead through fish/shellfish ingestion. It is important to consider the fact that lead is considered by USEPA (1995) to be a constituent not of concern to human health via bioaccumulation in fish. Lead in fish tends to partition to the scales, mucosal covering, and gills – parts of the fish that most humans consider inedible. For these reasons, health risks from exposure to lead are not quantified in this assessment.

5.1.5 Risk Characterization

The risk characterization combines the information presented in the Exposure Assessment with the information presented in the Toxicity Assessment to describe the type and magnitude of potential carcinogenic risks and non-carcinogenic hazards due to exposure to constituents originating from the Ash Site. The magnitude and types of risks depend on the nature, duration, and frequency of exposure to COPCs, and the characteristics of the exposed populations.

5.1.5.1 Characterization of Carcinogenic Effects

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e., excess individual lifetime cancer risk).

Based on the evidence that a constituent is a known or probable human carcinogen, a toxicity value that defines a quantitative relationship between dose and response (i.e., SF) is calculated. A SF converts estimated daily intakes averaged over a lifetime of exposure directly to incremental risk of an individual developing cancer. A critical assumption of this approach is that the dose-response relationship is a linear relationship in the low-dose portion of the dose-response curve. Under this assumption, the SF is a constant and risk will be directly related to intake. Thus, the linear form of the carcinogenic risk equation is usually applicable for estimating site risks. This linear low-dose equation is defined as:

$$Risk = CDI \times SF$$

where:

Risk = a unitless probability (e.g., 1×10^{-6}) of an individual developing cancer over a lifetime;

CDI = chronic daily intake averaged over 70 years (mg/kg-day); and

SF = slope factor, expressed in $(\text{mg/kg-day})^{-1}$.

5.1.5.2 Characterization of Non-Carcinogenic Effects

A chronic RfD or RfC is an estimate of the daily exposure to a human population, including sensitive subpopulations, that is unlikely to cause an increased incidence of deleterious health effects during a lifetime of exposure. Chronic RfD or RfC values are specifically developed to be protective for long-term exposure to a constituent.

For non-carcinogenic constituents, the measure used to describe the potential for non-carcinogenic toxicity to occur in an individual is evaluated by comparing the estimated exposure level over a specified time period (e.g., exposure duration) with the appropriate non-cancer toxicity value (i.e., RfD or RfC).

This ratio of exposure to toxicity is called a non-cancer hazard quotient (HQ):

$$HQ = \frac{CDI}{RfD}$$

where:

HQ = hazard quotient;
CDI = chronic daily intake (mg/kg-day); and
RfD = Reference dose (mg/kg-day).

The non-carcinogenic hazard quotient assumes that there is a level of exposure (e.g., RfD or RfC) below which it is unlikely for even sensitive subpopulations to experience adverse health effects.

For assessing the health impacts of several non-carcinogenic constituents, RfDs or RfCs are compared to exposure-specific intake rates of each COPC. A summation of these hazard quotients is termed the hazard index (HI). The aggregate HI is expressed as:

$$HI_T = \sum_k \frac{CDI_j}{RfD_j}$$

where:

HI_T = total hazard index for cumulative exposure scenarios for an individual;
k = k^{th} exposure pathway;
CDI_j = chronic daily exposure for the j^{th} constituent in each exposure medium; and
RfD_j = Reference dose for the j^{th} constituent.

If this ratio of the daily intake to the RfD or RfC exceeds 1.0 (unity) for the defined exposure scenario, this provides an indication that the exposed receptor may be subject to an adverse health impact and that further investigation should be undertaken. If the ratio is below unity, then it is generally assumed that no adverse impact to human health has or will occur.

The HI approach does have limitations and should be interpreted carefully based on the known aspects of additive toxic effects from exposure to mixtures of chemicals. First, because both the HQ and HI are ratios, after unity has been exceeded, the magnitude of the index has little bearing on the potential severity of adverse effects that may be anticipated. An HI of five does not indicate the non-cancer hazard is greater than a HI of three. Secondly, it is generally inappropriate to sum non-cancer hazard quotients for constituents that do not have similar toxic modes of action or that do not affect the same organ system. As presented in the previous section of this report, none of the sediment COPCs act on the same organ or system; therefore, it is inappropriate to add any of the individual HQ values.

5.1.5.3 Interpretation of Calculated Cancer Risk and Non-Cancer Hazard Quotients

Current USEPA guidance indicates that a site presents acceptable risk if the calculated cumulative cancer risk to a potentially exposed population is within the range of 1 in 10,000 to 1 in 1,000,000 (1.0×10^{-4} to 1.0×10^{-6}) and the acceptable HI for non-cancer adverse health effects is less than 1.0 (USEPA, 1991). Per DNREC (1999) guidance, cumulative carcinogenic risk should not exceed 1 in 100,000 (1×10^{-5}) and the cumulative non-carcinogenic HI should not exceed 1.0.

5.1.5.4 Calculated Carcinogenic Risks

Carcinogenic risks were calculated for the recreational fisherman receptor population that utilize the Indian River and Island Creek in the vicinity of Burton Island for their fishing grounds and trespass on Burton Island. The only complete exposure pathways for these receptors are the ingestion of recreationally caught fish and shellfish, incidental ingestion of soil, and dermal absorption of soil. Calculated carcinogenic risks for adult and child recreational fishermen are summarized in **Table 5.1-11** and are presented in **Tables M-1** through **M-5** provided in **Appendix M.**

Table 5.1-11

Summary of Calculated Carcinogenic Risks for Recreational Fisherman

	Adult Carcinogenic Risk	Child Carcinogenic Risk
Fish/Shellfish Ingestion (OU1)	5.2E-05	8.0E-06
Soil Ingestion (OU2)	5.6E-06	4.6E-05
Soil Dermal Absorption (OU2)	3.8E-08	1.3E-07
TOTAL :	5.8E-05	5.4E-05

These calculated risks were solely due to arsenic in surface soil and sediment. The total estimated carcinogenic risks are within the USEPA's recommended risk range of 1.0×10^{-4} to 1.0×10^{-6}, and marginally exceed DNREC's suggested guidance of 1×10^{-5}. As presented previously, the risks from fish/shellfish ingestion are associated with OU1, and the risks from ingestion of soil and dermal absorption of soil are associated with OU2. If illegal trespassing on Burton Island was limited to fewer than 16 events per year, then all of the calculated risks associated with exposure to surface material at OU2 would be less than the recommended risk levels specified by USEPA (risk $< 1.0 \times 10^{-4}$ to 1.0×10^{-6}) and DNREC (risk $< 1.0 \times 10^{-5}$).

5.1.5.5 Calculated Non-Carcinogenic Hazards

Non-carcinogenic hazards were calculated for the recreational fisherman receptor population that utilize the Indian River and Island Creek in the vicinity of Burton Island for their fishing grounds and trespass on Burton Island. The only complete exposure pathways for these receptors are the ingestion of recreationally caught fish and shellfish, incidental ingestion of soil, and dermal absorption of soil. Non-carcinogenic hazard quotients for adult and child fishermen are presented in the tables provided in **Appendix M** and are summarized in **Table 5.1-12** below:

Table 5.1-12
Constituent-Specific Non-Carcinogenic Hazard Quotients

COPC	Adult HQ	Child HQ
Arsenic	0.42	1.6
Cadmium	0.237	0.363
Chromium	0.001	0.002
Copper	0.027	0.041
Mercury	0.127	0.194
Nickel	0.139	0.213
Selenium	0.069	0.106
Zinc	0.025	0.038

COPC – constituent of potential concern
HQ – hazard quotient.

These estimated non-carcinogenic hazard quotients are less than the USEPA's and DNREC's recommended target hazard quotient of 1.0, except for arsenic, which slightly exceeds the target hazard index of 1.0 for children. As presented previously, the hazards from fish/shellfish ingestion are associated with OU1, and the hazards from ingestion of soil and dermal absorption of soil are associated with OU2. If illegal trespassing was limited to fewer than 16 events per year, then all of the calculated hazards associated with exposure to surface material at OU2 would be less than the recommended hazard levels (HQ < 1.0) specified by USEPA and DNREC.

5.1.6 Human Health Risk Assessment Uncertainty Analysis

There are a number of uncertainties that are inherent in the risk assessment process. General uncertainties related to the conservative aspect of the risk analysis process and methodologies are especially apparent in the exposure assessment. The USEPA paradigm for conducting human health risk assessments presently requires the use of point estimates for all parameters (e.g., chemical concentration, body weight, length of exposure, etc.) to establish risk estimates for exposure scenarios. Furthermore, the inherent conservatism in the upper-bound point estimate approach is an attempt to account for both variability and uncertainty with the use of conservative assumptions.

As single-point estimates do not provide a vehicle for conveying the heterogeneity or variability of the data, no associated measure of confidence can be provided as a means of examining exposure assessment or the completed risk analysis. Therefore, uncertainty analysis is generally limited to qualitative statements about the confidence placed in critical data or default input parameters used in the exposure assessment component used to build the human health risk assessment. An example of a conservative point estimate used in the exposure assessment is the use of an exposure duration of 30 years. This single point estimate is used under the assumption that an individual catches and eats recreationally caught fish and shellfish from the Indian River and Island Creek adjacent to the Ash Site (and nowhere else) for 30 years.

Site-specific uncertainty is introduced into this assessment due the fact that the sediment samples used to characterize sediment within Indian River and Island Creek were all collected from areas that have been classified as exhibiting severe and moderate erosion. There are significant stretches of shoreline along the Ash Site that exhibit little to no apparent erosion. Thus the sediment samples collected for this assessment represent ”worst case“ conditions in the vicinity of Burton Island, and most likely do not represent the condition of the sediment in the majority of the Indian River and adjacent coastal bays.

Uncertainty also exists in the quantification of exposure to COPCs via fish/shellfish ingestion. Since no biota sampling was conducted as part of this investigation, it was necessary to estimate concentrations of COPCs in fish and shellfish tissues. In order to accomplish this, USEPA (1999) recommended sediment-to-biota BAFs were used in conjunction with measured sediment concentrations. Sediment-to-benthic invertebrate BAFs were used to estimate tissue concentrations in both fish and shellfish since sediment-to-fish BAFs are not available. The lack of site-specific sediment-to-biota BAFs imparts a significant level of uncertainty to the exposure assessment portion of this risk assessment.

Significant uncertainty exists in the assumption that trespassers frequent Burton Island 78 times a year and are exposed to surface soil during each of their trespassing activities. Access to Burton Island is restricted on the western (landward) end of the island by a locked chain-link fence and "No Trespassing" signs are posted along the shoreline. Therefore, regular trespassing on the island is unlikely. If more realistic exposure frequencies for trespassers were assumed, the estimated carcinogenic risks and non-carcinogenic hazards would likely be less than the recommended guidelines.

Toxicity assessment relies upon the use of toxicity values (cancer SF, non-cancer RfDs) developed by the USEPA to evaluate potential chronic toxicity of COPCs. These toxicity values may be estimated from human data, but the process is largely dependent upon laboratory animal data generated from a variety of toxicology and safety testing studies conducted on constituents.

The carcinogen toxicity values, SFs, are derived from cancer bioassay or epidemiologic dose-response data to estimate carcinogenic risk at constituent concentrations that may be several orders of magnitude lower that the given dose or estimated exposure observed in the studies that form the basis of the assessment. A number of uncertainties are associated with this methodology.

- The extrapolation of observed carcinogenic effects at high doses used in animal cancer studies to possible cancer effects at substantially lower doses is based on the hypothesis that there is no threshold dose for carcinogens. No experimental evidence is available to support this thesis.
- The extrapolation of carcinogenic and non-carcinogenic effects in animals to effects in humans may not be appropriate for all constituents, particularly if there are large species differences in metabolism of the constituent.
- While the USEPA has established a weight-of-evidence classification for carcinogens,

the cancer risk algorithm does not utilize this weight-of-evidence and sums all carcinogen risks equally, whether a COPC is a known human carcinogen or only a suspected carcinogen.

Each of these three uncertainty factors tend to overestimate cancer risk.

Toxicity values derived to estimate chronic dosages that may induce non-cancer adverse effects also have a number of limitations. Unlike cancer risk assessment, by convention, non-cancer adverse effects are assumed to occur in a dose-response manner only after a threshold dose has been exceeded. This is the basis for the use of the RfD or RfC in estimating the HQ. If this ratio is greater than 1.0, such exposures may be considered hazardous. The HQ can only be used to qualitatively rank the possibility of adverse non-cancer effects occurring. The following uncertainties are probable with the use of the hazard index to describe non-cancer health hazards:

- RfDs are derived from NOAEL or LOAEL dose rates determined from animal studies or human exposure investigations. Depending on the quality of the available data, the NOAEL or LOAEL is divided by an uncertainty factor ranging from 1 to 10,000. Large uncertainty factors used in extrapolating animal effects to human effects may over-estimate non-cancer hazards.
- The hazard quotient approach assumes that all non-cancer adverse effects are additive. While this approach may be sound for assessing a series of constituents that have similar modes of action and act on the same target organ, it is clearly not appropriate for combining potential adverse effects for constituents with very different target organs and toxic insult outcomes.
- Summation of HQs to calculate a cumulative HI for an exposure scenario can generate a very large number. The HI is a ratio of estimated exposure compared to a "safe" exposure dose. A health hazard is indicated if this ratio exceeds 1. The magnitude of a calculated HI greater than 1 has little bearing on the potential severity of adverse effects.

The toxicity of several of the sediment COPCs (i.e. arsenic, mercury, chromium) varies according to the speciation of the metal and the various compounds which it forms in the environment. Arsenic and mercury are known to change their form based on surface soil and sediment conditions (e.g. pH, ORP, dissolved oxygen, etc.) and their form may fluctuate according to seasonal and/or tidal cycles. Therefore, the use of a single toxicity value (CSF or RfD) to characterize the toxicity of these constituents is an oversimplification of a sometimes very complex and ever changing biochemical system. The uncertainty introduced into the toxicity assessment portion of this risk assessment through the use of a single toxicity value for each COPC is potentially significant.

There is no consideration of antagonistic or synergistic effects of exposure to multiple constituents. The current state of science does not support assessing the toxicity of chemical mixtures; however, it is a known fact that certain chemicals can act to amplify or ameliorate other chemical's inherent toxicity. This uncertainty is inherent in all risk assessments using the current science and is potentially significant.

A number of other factors also contribute to uncertainties in the risk characterization. These uncertainties are attributable to the risk characterization procedure itself and to several site-specific factors.

Quantitative risk characterization is largely dependent upon laboratory-derived animal toxicity values (carcinogenic slope factors, non-carcinogenic RfDs and RfCs) for the constituents of potential concern. Toxicity values derived from animal studies are given the same weight as toxicity values derived from human data.

5.1.7 Human Health Risk Assessment Summary and Conclusions

A human health risk assessment was conducted to determine the types and magnitudes of exposures to constituents originating from the Ash Site and to determine the potential carcinogenic risks and non-carcinogenic health hazards posed by the estimated exposures.

For this assessment, COPCs were identified in surface soil as those constituents whose EPC exceeded the URS for the protection of human health based on restricted use in a critical water resource area and/or its associated BSV. The only constituent that was identified as a COPC in surface soil at OU2 was arsenic. COPCs were identified in sediment as those constituents that were identified as "Important Bioaccumulative Compounds" by USEPA (2000) and whose maximum detected concentration exceeds local background concentrations. If constituents were not identified as "Important Bioaccumulative Compounds" by USEPA (2000) or their maximum detected concentration did not exceed site-specific background concentrations, then the constituent was not identified as a COPC in sediment for this assessment and human health risks/hazards were not quantified. The COPCs that were identified in shoreline and offshore sediment samples are the following:

- Arsenic
- Cadmium
- Chromium
- Copper
- Lead
- Mercury
- Nickel
- Selenium
- Zinc

Based on current and expected future uses of the Ash Site, the only complete exposure pathways with potentially significant exposures to surface soil and sediment COPCs is the assessment of the recreational fisherman receptor population for potential exposures to COPCs via ingestion of fish/shellfish, incidental ingestion of soil and dermal absorption of soil while trespassing on Burton Island.

Carcinogenic risk for adult and child recreational fishermen were calculated to be 5.8×10^{-5} and 5.4×10^{-5}, respectively. These calculated risks were solely due to arsenic in surface soil and sediment. None of the other COPCs are considered carcinogenic.

The estimated carcinogenic risks are within the USEPA's recommended risk range of 1×10^{-4} to 1×10^{-6}, and marginally exceed DNREC's suggested limit of 1 x 10^{-5}. The risks from fish/shellfish ingestion are associated with OU1, and the risks from ingestion of soil and dermal absorption of soil are associated with OU2. Although fish/shellfish ingestion was assessed in conjunction with OU1 and OU3 and it was determined that the "level of contamination present at Burton Island did not pose an undue health risk to an adult or child who may be exposed to the contaminants from eating fish from the local waters" (DNREC, 2008), this potential exposure pathway was incorporated into the assessment of OU2 in order to estimate total cumulative risks/hazards experienced by the recreational fisherman receptor population. If illegal trespassing on Burton Island was limited to fewer than 16 events per year, then all of the calculated risks associated with exposure to surface material at OU2 would be less than the recommended risk levels specified by USEPA (risk < 1 x 10^{-4} to 1×10^{-6}) and DNREC (risk < 1 x 10^{-5}).

Non-carcinogenic hazard quotients for adult and child recreational fishermen were presented in **Table 5.1-12** above and again here for ease of reference:

Table 5.1-12

Constituent-Specific Non-Carcinogenic Hazard Quotients

COPC	Adult HQ	Child HQ
Arsenic	0.42	1.6
Cadmium	0.237	0.363
Chromium	0.001	0.002
Copper	0.027	0.041
Mercury	0.127	0.194
Nickel	0.139	0.213
Selenium	0.069	0.106
Zinc	0.025	0.038

COPC – constituent of potential concern.
HQ – hazard quotient.

The estimated non-carcinogenic hazard quotients are less than the USEPA's and DNREC's recommended target hazard index of 1.0, except for arsenic, which slightly exceeds the target hazard index of 1.0 for children. The hazards from fish/shellfish ingestion are associated with OU1, and the hazards from ingestion of soil and dermal absorption of soil are associated with OU2. If illegal trespassing was limited to fewer than 16 events per year, then all of the calculated hazards associated with exposure to surface material at OU2 would be less than the recommended hazard levels (HQ < 1.0) specified by USEPA and DNREC. Although fish/shellfish ingestion was assessed in conjunction with OU1 and OU3 and it was determined that the "level of contamination present at Burton Island did not pose an undue health risk to an adult or child who may be exposed to the contaminants from eating fish from the local waters" (DNREC, 2008), this potential exposure pathway was incorporated into the assessment of OU2 in order to estimate total cumulative risks/hazards experienced by the recreational fisherman receptor population.

It should be noted that the DNREC Division of Water Resources currently prohibits the harvesting of shellfish from the waters surrounding Burton Island and other areas of the Delaware Inland Bays due to the potential for bacterial pollution not related to the Ash Site or the Indian River Generating Plant. This shellfish harvesting prohibition effectively eliminates legal human exposures to shellfish from these prohibited areas (including the area surrounding Burton Island). There are no fish consumption advisories related to metals in the Delaware Inland Bays.

It is also interesting to note that in a recent study conducted to measure arsenic concentrations in marine fish in the Delaware Inland Bays, Greene and Crecelius (2006) found that fish migrating into the Inland Bays in the spring had higher concentrations of arsenic in their tissues than fish migrating out of the Inland Bays in the fall after spending the summer within the Inland Bays. These results indicate that the Inland Bays do not contribute significantly to the overall fish tissue burden of arsenic exhibited by migrating fish species.

Therefore, it can be concluded that site-related constituents in surface soil and sediment do not pose significant risks/hazards to the recreational fisherman receptor population except for arsenic, which has the potential for increased carcinogenic risk and non-carcinogenic hazard assuming conservative exposure parameters. If more realistic exposure parameters are considered, all of the estimated carcinogenic risks and non-carcinogenic hazards associated with exposure to surface material at OU2 are less than the recommended risk/hazard levels specified by USEPA and DNREC.

5.2 Screening Level Ecological Risk Assessment

The SLERA presented herein has been conducted in accordance with the guidelines set forth in the *Remediation Standards Guidance under the Delaware Hazardous Substance Cleanup Act* (DNREC, 1999) which stipulates that SLERAs be conducted according to *Ecological Risk Assessment Guidance for Superfund (ERAGS): Process for Designing and Conducting Ecological Risk Assessments* (USEPA, 1997) and *Framework for Ecological Risk Assessment* (USEPA, 1992). A SLERA encompasses Steps 1 and 2 of the USEPA's eight-step ecological risk assessment process (USEPA, 1997). Step 1 consists of a screening level problem formulation and an ecological effects evaluation. Step 2 consists of a screening level exposure assessment and risk/hazard estimation. The major components of this SLERA are summarized below.

- **Environmental Setting** – Information regarding the location of the facility with respect to the local ecological habitats and receptors is provided as context for the SLERA.
- **Identification of COPECs** – Identification of the site-related constituents and their respective exposure point concentrations.
- **Problem Formulation** – Problem formulation includes identification of ecological receptors, identification of COPEC exposure pathways, selection of assessment endpoints, and selection of measurement endpoints.
- **Analysis** – Potential for exposure and ecological effects are assessed for each COPEC and measurement endpoint receptor.
- **Risk Characterization** – The ecological exposure and effects information are used to estimate ecological hazard quotients (EHQs) for each combination of COPEC and measurement endpoint receptor.

- **Uncertainty Analysis** – Uncertainties relative to each task of the SLERA are discussed with regard to their potential effect on the results of the SLERA and the magnitude of their effect.
- **Summary and Conclusions** – The results of the SLERA are summarized and conclusions regarding the need for further action are documented and justified.

5.2.1 Environmental Setting

The existing ecology associated with the OU2, particularly Burton Island, Indian River, and Island Creek, were discussed previously in Section 2.0 of this report. This section summarizes the environmental setting, especially as it pertains to the ecological screening level problem formulation. Burton Island is a peninsula that extends into the Indian River Estuary, with the Indian River to the north and east, Island Creek to the south, and the Indian River Generating Station to the west. The upland habitat of Burton Island (which is the subject of this SLERA) is discussed below, followed by a discussion of the riparian habitat near the water's edge, and the aquatic habitat of the adjacent tidal waters.

As described in Sections 2 and 3 of this report, there are three ponds located near the eastern tip of Burton Island which have been designated Pond SW, Pond SE, and Pond NE as shown in **Figure 2.4-2**. These ponds were investigated as part of this RI to determine if the environmental conditions in these ponds differed significantly from the conditions in OU1 and OU3 which were evaluated in the FE (Shaw, 2008).

The three ponds exhibited surface water that ranged from brackish to saline. None of the ponds contained fresh water and none of the surface water in these three ponds would be suitable as a drinking water source for ecological receptors due to their salinity. Statistical analysis of the sediment data from these three ponds compared to sediment data from OU1 and OU3 indicated that the constituent concentrations in sediment were similar for all detected constituents except for aluminum, selenium, and vanadium. Although aluminum, selenium, and vanadium were found in higher concentrations in the three ponds compared to the sediment in OU1 and OU3, the conclusions of the FE are applicable to the three ponds investigated as part of this RI. The conclusions of the FE with regard to sediment for ecological receptors were:

1) no ecological hazard from exposure to sediment through food web interactions;
2) possible but not probable potential for adverse effects on benthic invertebrates due to arsenic and barium in sediment; and
3) no further ecological evaluation is recommended for sediment.

Statistical analysis of the surface water data from the three ponds compared to surface water data from OU1 and OU3 indicated that all of the constituent concentrations in the three ponds were similar to the data from OU1 and OU3, except for arsenic, selenium, and vanadium. Although the concentrations of these three constituents were higher in the pond water than they were in the water samples from OU1 and OU3, the conclusions of the FE are applicable to the three ponds investigated as part of this RI. The conclusions of the FE with regard to surface water were:

1) no ecological hazard from exposure to surface water through food web interactions;
2) the likelihood of adverse effects from exposure to arsenic and barium in surface water is minimal; and
3) no further ecological evaluation is recommended for surface water.

Therefore, no additional assessment of the three ponds near the eastern tip of Burton Island is warranted, and the conclusions of the FE (Shaw, 2008) are applicable to these three ponds.

Upland Habitat: The western portion of Burton Island contains the Indian River Generating Station and associated buildings and paved areas, and the larger area to the east is the Ash Site. These relatively recently disturbed areas now support a variety of upland vegetation. Tree species observed during recent site work were primarily fast growing and early successional species including loblolly pine (*Pinus taeda*), black cherry (*Prunus serotina*), eastern red cedar (*Juniperus virginiana*), sweetgum (*Liquidambar styraciflua*), and devil's-walking-stick (*Aralia spinosa*). As presented in Section 2.4, the dominant vegetative communities within OU2 and their percent coverage of the surface area of OU2 include the following:

- Common reed dominated upland 29.1%
- Bayberry/loblolly pine dominated upland 21 %
- Loblolly pine/common reed dominated upland 14.2 %
- Black locust dominated upland 13.9 %
- Bayberry/red maple dominated wetland transition 11.3 %

Other vegetative communities and habitat types each covered less than 5 percent of the total area of OU2.

Although wildlife species survey data are not available specifically for Burton Island, a species checklist for the nearby AWA shows that the following mammals may be present:

- White-tailed Deer
- Grey Squirrel
- Delmarva Fox Squirrel
- Southern Flying Squirrel
- Eastern Cottontail
- Raccoon
- Striped Skunk
- Red Fox
- Gray Fox
- River Otter
- Muskrat
- Meadow Vole
- Eastern Mole
- Masked Shrew
- White-footed Mouse
- Cotton Rat

The AWA data also include 162 species of birds, 12 species of reptiles and 12 species of amphibians (Gano, 1996). A detailed description of the habitats and dominant species present within OU2 is presented in Section 2.4.2 of this report.

Riparian Habitat: Vegetation in the riparian and intertidal areas of Burton Island include the shrubs eastern baccharis (*Baccharis halimifolia*) and marsh elder (*Iva frutescens*), as well as the grasses smooth cordgrass (*Spartina alterniflora*), and common reed (*Phragmites australis*). Fiddler crab (*Uca pugnax*) colonies were observed among *Spartina alterniflora* growth in the intertidal zone on the southeast portion of the Island. The riparian areas of Burton Island also provide habitat for wading birds including great egret (*Ardea alba*), snowy egret (*Egretta thula*), and great blue herron (*Ardea herodias*). These birds prey on the abundant small fish in the shallow waters surrounding Burton Island. Osprey (*Pandion haliaetus*) have historically had robust populations in the region, and several breeding pairs utilize nest platforms erected on Burton Island. These fish-eating raptors prey on menhaden that were observed to be abundant in the vicinity of Burton Island, as well as other fish species in the estuary and near-shore ocean waters.

Aquatic Habitat: The waters adjacent to Burton Island, Indian River and Island Creek, are tidal estuarine waters with a salinity range of about 10-22 parts per thousand (ppt). The waters are part of a tidal system that includes Indian River Bay and Rehoboth Bay, and which discharges to the Atlantic Ocean through the Indian River Inlet. The waters near Burton Island are quite shallow as are the bays, which have an average depth of 3-8 feet. The estuary is poorly flushed by tidal exchange, meaning that it takes numerous tidal cycles to remove constituents from the system (DNREC, 2001). The overall condition of the Delaware Inland Bays (not specific to the areas surrounding Burton Island) has been rated “fair” based on four indices utilized by the USEPA National Coastal Assessment (NCA). The indices evaluated the Delaware Inland Bay’s water quality as fair, sediment quality and benthic invertebrate community quality as poor, and fish tissue quality was rated good (USEPA, 2006).

It should be noted that the DNREC Division of Water Resources currently prohibits the harvesting of shellfish from the waters surrounding Burton Island and other areas of the Delaware Inland Bays due to the potential for bacterial pollution not related to the Ash Site or the Indian River Generating Plant. There are no fish consumption advisories related to metals in the Delaware Inland Bays.

It is also interesting to note that in a recent study conducted to measure arsenic concentrations in marine fish in the Delaware Inland Bays, Greene and Crecelius (2006) found that fish migrating into the Inland Bays in the spring had higher concentrations of arsenic in their tissues than fish migrating out of the Inland Bays in the fall after spending the summer within the Inland Bays. These results indicate that the Inland Bays do not contribute significantly to the overall fish tissue burden of arsenic exhibited by migrating fish species.

Rare, Threatened and Endangered Species: For the purposes of the FE (Shaw, 2008), as well as in preparation for the ongoing shoreline stabilization activities in OU1, the USFWS and the NMFS were requested to provide information as to the possible presence of threatened and endangered species in the vicinity of Burton Island. The response from the USFWS indicated that, except for occasional transients, no proposed or federally listed species were known to exist within the project area. The NMFS response indicated that several species of sea turtles including loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempi*) and green sea turtle (*Chelonia mydas*) may be found in the Indian River near Burton Island. In addition, their response indicated that no effects to these species would occur from the shoreline stabilization activities.

The DNREC Natural Heritage and Endangered Species Program has not formally surveyed the site although Robert Coxe, an ecologist with the Delaware Natural Heritage Program, accompanied field survey teams for one day of the vegetation and habitat survey in October 2009. The field survey team did not observe any state rare or federally-listed plants, animals, or natural communities within OU2 although no written commentary has been provided by the Delaware Natural Heritage Program. DNREC does have records of black vulture (*Coragyps atratus*) in the vicinity of Burton Island, but according to DNREC "this species should not be impacted unless the forested portion of the parcel is going to be disturbed. In addition, there are two bald eagle nests upstream and trees along the shore are likely utilized for roosting and foraging" (DNREC, 2007). It should also be noted that during October of 2000, a loggerhead sea turtle (*Caretta caretta*) was found trapped and swimming within the cooling water intake canal of the Indian River Generating Station. The frequency of this species occurrence within the water intake canal or interactions with the generating station is currently unknown. Sea turtle usage of the general area surrounding Burton Island and within the Delaware and Maryland inland bays has been documented by sightings. Loggerhead sea turtles are state listed as endangered, and federally listed as threatened and are protected by the Endangered Species Act.

5.2.2 Identification of Constituents of Potential Ecological Concern

The nature and extent of constituents, as it relates to OU2, is described in Section 3.0 of this report. In order to identify the COPECs for the OU2 SLERA, the data collected as part of the nature and extent evaluation were compared to the DNREC URS for the protection of the environment presented in *Remediation Standards Guidance Under the Delaware Hazardous Substance Cleanup Act* (DNREC, 1999).

Surface soil on Burton Island was characterized through the collection and analysis of 14 composite surface soil samples as described in Section 3.1. **Table 5.2-1** presents a summary of the surface soil data collected for the OU2 RI.

The surface soil samples exhibited concentrations of antimony, beryllium, cobalt, and lead that were less than their respective URS values and were not identified as surface soil COPECs. Additionally, the surface soil samples exhibited concentrations of chromium, manganese, and zinc that were less than their respective background screening values and were not identified as surface soil COPECs.

Per USEPA (2003a) guidance, aluminum toxicity is associated with soluble aluminum only. Numeric screening values for aluminum are considered inappropriate due to the uncertainty in the solubility of aluminum in any given soil type under different environmental conditions. Alternatively, potential ecological risks associated with exposure to aluminum are associated with soil pH. Aluminum is identified as a COPEC only if the soil pH is less than 5.5 (USEPA, 2003a). The pH of all the surface soil samples collected from OU2 were greater than 5.5 except for one sample; therefore, aluminum was not identified as a surface soil COPEC.

Iron was detected at a maximum concentration that was 1.1 times the BSV for iron. Although the maximum detected concentration of iron exceeds the BSV, iron is not present at concentrations that grossly exceed the naturally occurring levels; therefore, it is likely that the concentrations of this macro-nutrient found at OU2 are easily regulated by most organisms. Iron is generally non-toxic to plants at pH levels between 5 and 8. Toxicity of iron is associated with soluble iron only; therefore, numeric screening values for iron are considered inappropriate due to the uncertainty in the solubility of iron in any given soil type under different environmental conditions. Iron is identified as a COPEC only if the soil pH is less than 5 (USEPA, 2003b). Since the pH of the surface soil samples from OU2 is greater than 5 in all but one sample, iron is not considered a COPEC in surface soil at OU2.

Copper was detected in two surface soil samples at concentrations that exceeded the URS, but the 95%-UCL concentration was less than the URS; therefore copper was not identified as a surface soil COPEC.

Table 5.2-1

Surface Soil Data Summary and Constituent of Potential Ecological Concern Identification

Chemical	Background Screening Value [c] (mg/kg)	Human Health URS[d] (mg/kg)	Maximum Detected Conc. (mg/kg)	Minimum Detected Conc. (mg/kg)	Mean Detected Conc. (mg/kg)	Detection Frequency	95%-UCL Conc.[a] (mg/kg)	Distribution [a]	Recommended Method [a]	Exposure Point Concentration [b] (mg/kg)	Constituent of Potential Concern?
Inorganics :											
ALUMINUM	2.39E+04	2.00E+05	1.97E+04	5.45E+03	1.28E+04	14 / 14	1.46E+04	Normal	Student's-t	1.46E+04	no (2)
ANTIMONY	1.12E+01	2.70E+01	1.20E+00	4.40E-01	8.83E-01	13 / 14	1.02E+00	Normal	KM (t)	1.02E+00	no (1,2)
ARSENIC	1.98E+01	3.00E+00	2.03E+02	2.70E+01	1.27E+02	14 / 14	1.50E+02	Normal	Student's-t	1.50E+02	**YES**
BARIUM	1.14E+02	1.40E+04	7.44E+02	7.41E+01	4.37E+02	14 / 14	5.26E+02	Normal	Student's-t	5.26E+02	**YES**
BERYLLIUM	1.70E+00	4.10E+02	4.50E+00	4.80E-01	2.71E+00	14 / 14	3.19E+00	Normal	Student's-t	3.19E+00	no (1)
CALCIUM	1.08E+03	NA	3.92E+03	5.65E+02	2.01E+03	14 / 14	2.42E+03	Normal	Student's-t	2.42E+03	no (3)
CHROMIUM, TOTAL	4.57E+01	3.50E+01	4.47E+01	7.90E+00	2.93E+01	14 / 14	3.41E+01	Normal	Student's-t	3.41E+01	no (2)
COBALT	6.00E+00	2.20E+01	1.77E+01	3.20E+00	1.27E+01	14 / 14	1.45E+01	Normal	Student's-t	1.45E+01	no (1)
COPPER	7.80E+00	8.20E+03	5.99E+01	1.22E+01	4.14E+01	14 / 14	4.77E+01	Normal	Student's-t	4.77E+01	no (1)
CYANIDE	NA	1.50E+01	2.90E-01	1.70E-01	3.08E-01	2 / 14	2.90E-01	Nonparametric	KM (% Bootstrap)	2.90E-01	no (1)
IRON	7.29E+04	6.10E+04	4.97E+04	1.08E+04	3.29E+04	14 / 14	3.78E+04	Normal	Student's-t	3.78E+04	no (2)
LEAD	3.31E+01	1.00E+03	3.57E+01	1.08E+01	2.22E+01	14 / 14	2.60E+01	Normal	Student's-t	2.60E+01	no (1,2)
MAGNESIUM	1.02E+04	NA	4.80E+03	3.93E+02	1.13E+03	14 / 14	2.50E+03	Nonparametric	Chebyshev (Mean,Sd)	2.50E+03	no (2,3)
MANGANESE	1.85E+03	4.10E+03	1.01E+02	2.22E+01	6.75E+01	14 / 14	7.64E+01	Normal	Student's-t	7.64E+01	no (2)
MERCURY	1.60E-01	1.00E+01	8.10E-01	1.10E-01	4.63E-01	14 / 14	5.58E-01	Normal	Student's-t	5.58E-01	**YES**
NICKEL	1.50E+01	6.50E+02	4.63E+01	7.20E+00	3.23E+01	14 / 14	3.71E+01	Normal	Student's-t	3.71E+01	**YES**
POTASSIUM	2.25E+03	NA	2.94E+03	5.60E+02	1.42E+03	14 / 14	1.70E+03	Normal	Student's-t	1.70E+03	no (2,3)
SELENIUM	3.50E+00	2.60E+01	7.20E+00	1.60E+00	3.68E+00	14 / 14	4.30E+00	Normal	Student's-t	4.30E+00	**YES**
SODIUM	6.18E+02	NA	4.63E+02	7.31E+01	1.75E+02	14 / 14	2.24E+01	Gamma	Approx Gamma	2.24E+01	no (2,3)
THALLIUM	7.50E-01	1.40E+01	2.20E+00	4.60E-01	1.34E+00	14 / 14	1.58E+00	Normal	Student's-t	1.58E+00	**YES**
VANADIUM	8.36E+01	1.40E+03	8.99E+01	1.66E+01	6.10E+01	14 / 14	7.10E+01	Normal	Student's-t	7.10E+01	no (2)
ZINC	1.77E+02	2.30E+03	8.50E+01	1.29E+01	5.32E+01	14 / 14	6.26E+01	Normal	Student's-t	6.26E+01	no (2)
General Chemistry :											
TOC	NA	NA	1.34E+05	1.66E+04	8.44E+04	14 / 14	--	--	--	--	no
PH	NA	NA	8.22E+00	4.62E+00	6.38E+00	14 / 14	--	--	--	--	no

[a] Nature of distribution and 95% UCL (Upper confidence limit) determined using ProUCL Version 4.00.05 (U.S. Environmental Protection Agency (USEPA), 2010b, Office of Research and Development, Las Vegas, Nevada, and Technology Support Center, Atlanta, GA, May, on line at http://www.epa.gov/esd/tsc/TSC_form.htm.
[b] Exposure point concentration (EPC) is equal to 95% UCL or maximum detected concentration, whichever is lower.
[c] Background Screening Values (BSV) are the 95% UTL concentrations defined in the *Area 6 Remedial Investigation, Dover Air Force Base, Dover, DE* (Dames & Moore, 1994).
[d] Delaware Uniform Risk-Based Remediation Standard for the protection of human health assuming restricted use in a critical water resource area.
EPC - Exposure point concentration
KM - Kaplan-Meier Method.
mg/kg – milligrams per kilogram.
ND - No data.
NA - Not applicable.
UCL - Upper confidence limit.
Rationale for exclusion as a COPEC:
1 - Exposure point concentration is less than the Uniform Risk-Based Remediation Standard (URS) for Protection of the Environment
2 - Exposure point concentration is less than the Background Screening Value (BSV)
3 - Essential macro-nutrient

Vanadium was detected in one surface soil sample at a concentration that exceeded the BSV; however, the 95%-UCL concentration was less than the BSV. Therefore, vanadium was not identified as a surface soil COPEC.

Calcium, magnesium, potassium, and sodium are identified as essential macro-nutrients that are essential for maintaining routine function in most organisms (USEPA, 1989). Most organisms have mechanisms designed to regulate nutrient fluxes within their systems; therefore, these nutrients are generally only toxic at very high concentrations. The exposure point concentration for calcium was 2.2 times the BSV and the exposure point concentrations for magnesium, potassium, and sodium were all less than their respective BSVs; therefore, these essential macro-nutrients were not identified as COPECs in surface soil at OU2.

Arsenic, barium, mercury, nickel, selenium, and thallium were detected in numerous surface soil samples at concentrations that exceeded their respective URS values and BSVs and were identified as COPECs in surface soil at OU2 for the purpose of the SLERA (**Table 5.2-1**). Identification of these parameters as COPECs does not imply that there is a potential risk due to these parameters or that these parameters are necessarily related to site activities, but that they will receive further attention within the context of the SLERA before making such a determination.

5.2.3 Problem Formulation

Problem formulation is the first step in the SLERA process and establishes the breadth and focus of the SLERA. Problem formulation establishes the exposure scenarios to be used in the risk analysis and risk characterization phases of the SLERA. The problem formulation contains the following components:

- Identification of ecological receptors in the assessment area;
- Identification of simplified food webs;
- Development of an ecological conceptual site model;
- Selection of assessment endpoints; and
- Measurement of effects.

5.2.3.1 Potential Ecological Receptors

The Ash Site is comprised of approximately 94 upland acres with approximately 11,550 feet of shoreline in the western portion of Indian River Bay. Indian River forms the northern and eastern boundaries of the Ash Site, Island Creek is on the southern boundary and the Indian River Generating Station is on the western boundary of the Ash Site.

The western portion of Burton Island contains the Indian River Generating Station and associated buildings and paved areas, and the larger area to the east is the Ash Site. These relatively recently disturbed areas now support a variety of upland vegetation. Tree species observed during recent site work were primarily fast growing and early successional species including loblolly pine (*Pinus taeda*), black cherry (*Prunus serotina*), eastern red cedar (*Juniperus virginiana*), sweetgum (*Liquidambar styraciflua*), and devil's-walking-stick (*Aralia spinosa*).

Land use on Burton Island is restricted to Indian River Generating Station personnel only, and access to the Ash Site is controlled by a locked ten-foot high chain-link fence.

The upland portions of the Ash Site could likely support a variety of wildlife species. Although wildlife species survey data are not available specifically for Burton Island, a species checklist for the nearby Assawoman Wildlife Area (AWA) shows that the following mammals may be present:

- White-tailed Deer
- Grey Squirrel
- Delmarva Fox Squirrel
- Southern Flying Squirrel
- Eastern Cottontail
- Raccoon
- Striped Skunk
- Red Fox
- Gray Fox
- River Otter
- Muskrat
- Meadow Vole
- Eastern Mole
- Masked Shrew
- White-footed Mouse
- Cotton Rat

The AWA data also include 162 species of birds, 12 species of reptiles and 12 species of amphibians (Gano, 1996) that may also be present at the Ash Site.

The riparian and aquatic habitats that occur along the shoreline of the Ash Site (OU1 and OU3) are addressed in the FE report (Shaw, 2008) and are not considered in this SLERA.

Given the variety of habitats present in the upland portion of Burton Island and the riparian and aquatic zones along the shoreline of Burton Island, a large variety of ecological receptors could potentially be exposed to ash material originating from the Ash Site. As this assessment addresses OU2, only terrestrial ecological receptors are considered in this assessment. There are a number of feeding guilds and food web relationships that occur within the terrestrial ecosystem of OU2. The following section describes these food web relationships and how they are addressed in this risk assessment.

5.2.3.2 Simplified Food Web

Simplified food webs are developed to help identify the representative feeding guilds that might be directly or indirectly exposed to COPECs at, or in the vicinity of the Ash Site. These food webs present the following information:

- Abiotic media (e.g., soil, surface water, sediment);
- Trophic levels, including: producers (trophic level 1), primary consumers (trophic level 2); secondary consumers (trophic level 3), and carnivores (trophic level 4);
- Trophic level compartments represented by feeding guilds; and
- Major dietary relationships between trophic level compartments.

Food webs show interlocking patterns of food chains. A food chain is a straight line from a food source (e.g. plants) to a series of organisms feeding on the source, or on other organisms feeding on the source. A food web depicts how energy (and in this case COPECs) may be transferred within an ecosystem. A food chain represents a potential COPEC exposure pathway; its importance depending upon the receptor dietary habits and the specific COPEC.

Food webs for this assessment were developed using the "community approach" suggested in USEPA (1999), which includes the following: 1) identification of potential receptors in a given habitat for grouping into feeding guilds; 2) organizing food web structure by trophic level; and 3) defining dietary relationships between guilds and communities. The result is a complete food web for each habitat type.

The first step in developing a habitat-specific food web is the identification of the major feeding guilds present in the modeling domain, based on dietary habits and feeding strategies. Once the major feeding guilds are identified (e.g., herbivore, omnivore, invertivore, carnivore, piscivore), receptors are grouped by class (e.g., mammals, birds). Lower trophic level organisms (e.g., terrestrial vegetation, terrestrial invertebrates) are grouped into their respective communities by the media they inhabit (e.g., soil) and are assessed independently of the food web models.

Each food web is organized by trophic level. The first trophic level contains the primary producers or the green plants. These primary producers are the source of food for members of the second trophic level. The second trophic level is often referred to as the primary consumers and is composed of animals that eat plants (herbivores) and animals that subsist on detritus found in sediment and soil (detritivores). The third trophic level contains omnivores and carnivores. Omnivores are animals that eat both plant and animal matter, while carnivores eat primarily animal matter. The fourth trophic level contains primarily carnivores that occupy the top of the food web. Some species occupy more than one trophic level at a time depending on life stage. Although many species have complex diets, it is assumed for this assessment that the majority of each species' diet is composed of a limited number of prey items and, therefore, a limited number of feeding guild interactions.

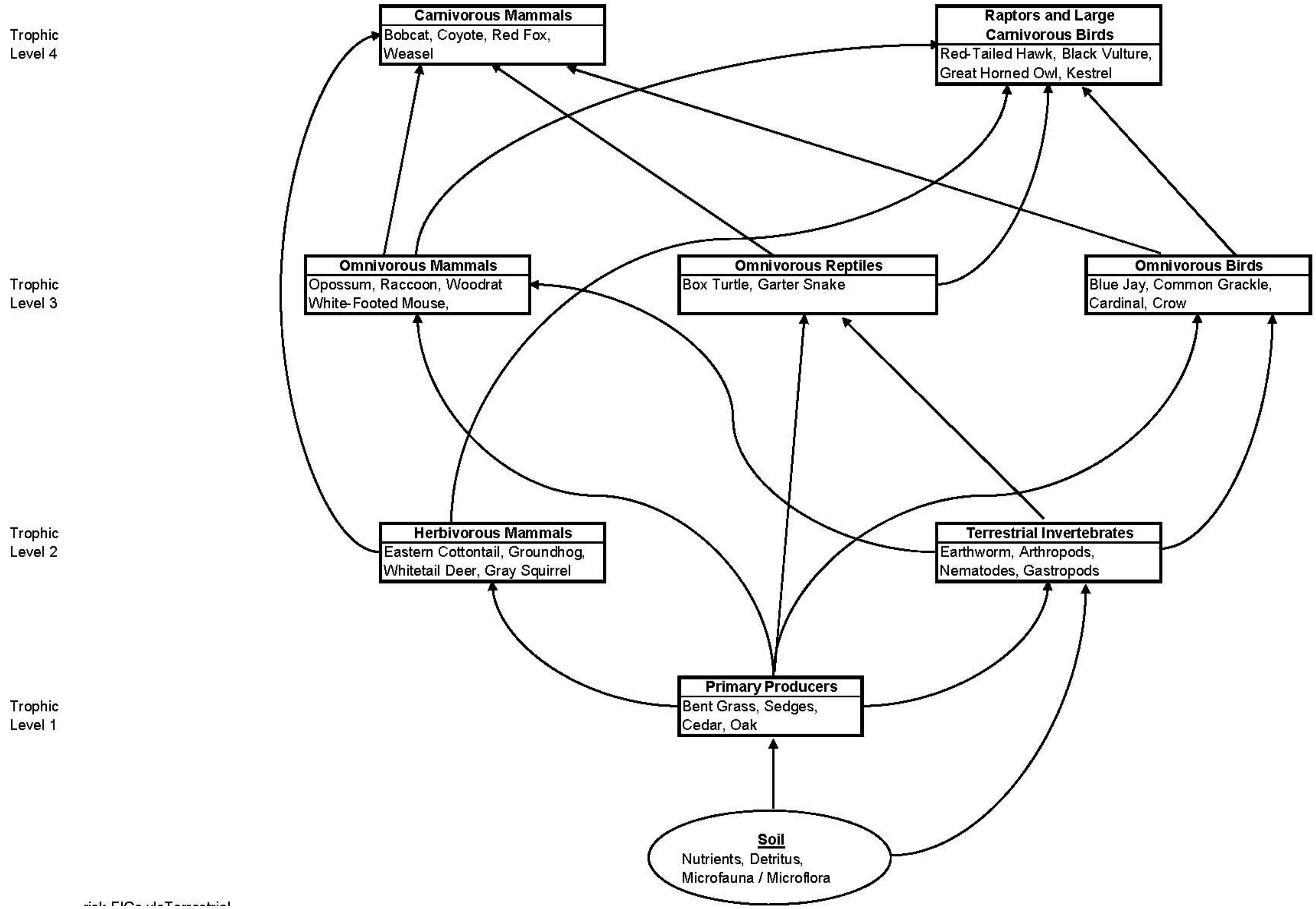
The various food chains within each food web represent potential COPEC exposure pathways. A food web has been developed for the terrestrial ecosystem present at OU2. The boxes on the food web figure represent feeding guilds (and representative species occupying that feeding guild), which are groups of organisms that exploit similar food resources. The terrestrial food web with representative species for each of the major feeding guilds is presented in **Figure 5.2-1**.

Terrestrial food webs are all based on terrestrial exposures; however, they also incorporate exposure to surface water due to ingestion of drinking water, if suitable drinking water sources are available on-site. In the case of OU2, suitable drinking water sources are not available on-site at OU2. The surrounding surface water bodies (Indian River and Island Creek) are saline and the on-site ponds are brackish to saline, which renders them unsuitable for drinking. Trophic level 1 of the terrestrial food web consists of the primary producers (terrestrial plants) which will vary depending on the habitat. These organisms represent the basis of the food chain and also provide shelter and habitat for higher trophic level species.

Trophic level 2 of the terrestrial food web consists of the herbivores (herbivorous mammals and herbivorous birds) and terrestrial invertebrates. The major route of exposure for terrestrial herbivores and invertebrates is through the ingestion of plants that may have accumulated COPECs from the soil. Bird diets can vary greatly and numerous bird species may also be considered herbivorous either all or part of the year, depending on conditions such as prey availability. Terrestrial herbivores such as the Eastern cottontail (*Sylvilagus floridanus*), groundhog (*Marmota monax*), whitetail deer (*Odocoileus virginianus*) and eastern gray squirrel (*Sciurus carolinensis*) could occur at OU2. Herbivorous birds such as the Canada goose (*Branta canadensis*) could also occur at OU2.

Figure 5.2-1

Terrestrial Food Web



Trophic level 3 of the terrestrial food web is occupied by the omnivores and invertivores. Omnivorous mammals, omnivorous birds, and omnivorous reptiles occupy this trophic level. Invertivorous mammals and birds may also occupy this trophic level. Omnivorous organisms may consume both trophic level 1 plant and trophic level 2 animal matter, and may feed almost exclusively on one or the other depending on seasons and prey population conditions. Invertivores have diets that consist almost exclusively of invertebrates. Typical omnivorous species that could occur in the terrestrial habitats at OU2 include omnivorous mammals such as the white-footed mouse (*Peromyscus leucopus*), red fox (*Vulpes vulpes*), opossum (*Didelphis marsupialis*) and raccoon (*Procyon lotor*). Omnivorous birds such as the American robin (*Turdus migratorius*), blue jay (*Cyanocitta cristata*), and American crow (*Corvus brachyrhynchos*) could also occur in the terrestrial habitats at OU2. Invertivorous mammals such as the short-tailed shrew (*Blarina brevacauda*) and invertivorous birds such as the American woodcock (*Scolopax minor*) could also occur in the terrestrial habitats at OU2.

Trophic level 4 is made up of carnivores and raptors. Carnivores are meat-eating animals and are, therefore, potentially exposed to COPECs through consumption of prey animals that may have accumulated COPECs in their tissues. Carnivores are quite often top predators in a local food web and are often subject to exposure to COPECs that have bioaccumulated in lower trophic level organisms or biomagnified through the food web. Food web exposures for carnivores are based on the consumption of prey animals that have accumulated COPECs from various means. Smaller herbivores, omnivores, invertivores, and other carnivores may consume soil, surface water, sediment, plant, and animal material as food and accumulate COPECs in their tissues. Subsequent ingestion of these prey animals by carnivorous animals would expose them to COPECs.

Most inorganic compounds are not accumulated in animal tissues to any great extent (Shugart, et al., 1990 and U.S. Army Environmental Hygiene Agency, 1994). Therefore, food web exposures to these chemicals are expected to be minimal. Carnivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while feeding, grooming, or other activities.

Typical carnivorous birds that occupy terrestrial habitats like those in the vicinity of OU2 include the red-tailed hawk (*Buteo jamaicensis*), black vulture (*Coragyps atratus*), and great horned owl (*Bubo virginianus*). Carnivorous mammals that could occur in the terrestrial habitats in the vicinity of OU2 include the bobcat (*Lynx rufus*), coyote (*Canis latrans*), and longtail weasel (*Mustela frenata*).

There may be a number of different terrestrial and aquatic food webs that are active on, and in the near vicinity of Burton Island. However, almost all of the food webs have species representing the four major trophic levels and feeding strategies. Because ecological risk assessments assess potential impacts to feeding guilds and not specific species, this risk assessment utilizes the terrestrial food web described above to assess all terrestrial habitats in the vicinity of the Ash Site. Additionally, toxicity information for ecological receptors is applicable to avian or mammalian species in general and is not species-specific, lending further credence to the use of generalized food webs to account for exposures to various terrestrial habitats.

This food web is used in subsequent sections of the ecological risk assessment to formulate assessment endpoints and develop measures of effect.

5.2.3.3 Ecological Conceptual Site Model

Figure 5.2-2 presents an ecological conceptual site model (Eco-CSM) which depicts the various source-pathway-receptor combinations possible for ash material at OU2.

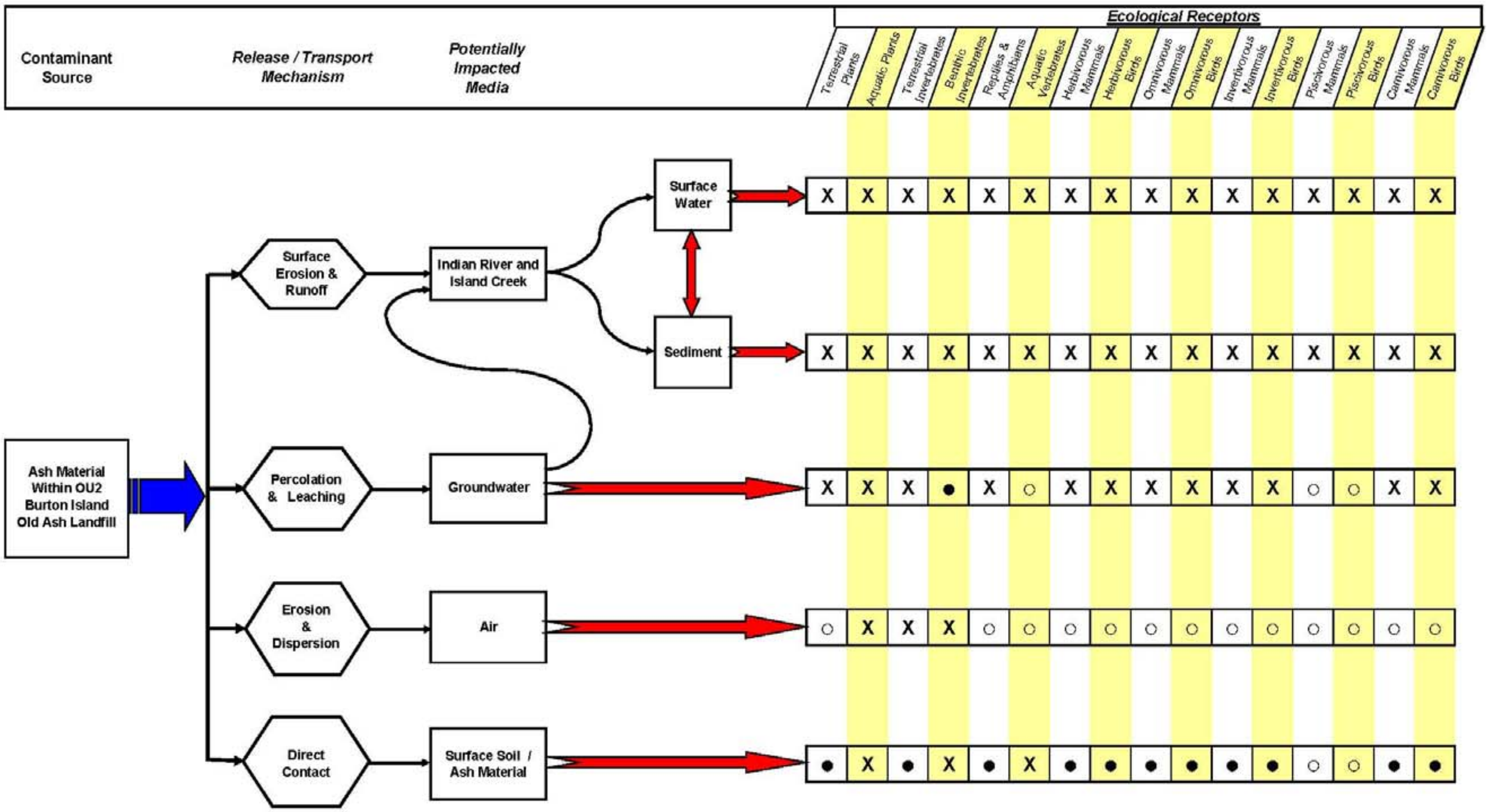
The source of COPECs in this assessment is the ash material that has been placed at the Ash Site. Constituents that become incorporated into abiotic media (e.g. soil) as a result of environmental fate and transport processes are available for direct exposure by receptor species and may also move through various environmental compartments via a number of transport mechanisms, many of which are chemical-specific. Constituents incorporated into soil are available for direct contact and ingestion by various terrestrial ecological receptors.

Constituents in soil may also be absorbed through the roots of vascular plants. If soil constituents are absorbed by plants, they may then be available for ingestion by herbivores and omnivores, with the potential to be transferred through the food web. Terrestrial invertebrates that live in constant contact with the soil may accumulate constituents from the soil. Ingestion of the terrestrial invertebrates by invertivores and other animals could transfer the soil constituents upward through the food web.

Erosional processes may transport ash material from the location of its original deposition to low-lying areas and/or to nearby water bodies (Indian River and Island Creek). The surface water and sediment in the water bodies surrounding the Ash Site (OU1 and OU3) were assessed in the FE (Shaw, 2008) and are not specifically assessed in this SLERA.

Figure 5.2-2

Ecological Conceptual Site Model



Potentially Impacted Media	Terrestrial Plants	Aquatic Plants	Terrestrial Invertebrates	Benthic Invertebrates	Reptiles & Amphibians	Aquatic Vertebrates	Herbivorous Mammals	Herbivorous Birds	Omnivorous Mammals	Omnivorous Birds	Invertivorous Mammals	Invertivorous Birds	Piscivorous Mammals	Piscivorous Birds	Carnivorous Mammals	Carnivorous Birds
Surface Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sediment	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Groundwater	X	X	X	●	X	○	X	X	X	X	X	X	○	○	X	X
Air	○	X	X	X	○	○	○	○	○	○	○	○	○	○	○	○
Surface Soil / Ash Material	●	X	●	X	●	X	●	●	●	●	●	●	○	○	●	●

Key To Potential Exposure Routes

- ● - Potentially complete exposure pathway
- X - Incomplete exposure pathway
- ○ - Potentially complete exposure pathway but insignificant

5.2.3.4 Assessment Endpoints

Using the food web described in the previous section, assessment endpoints are selected to focus the risk analysis and characterization. An assessment endpoint is an expression of the ecological attribute that is to be protected (Suter, 1989). A summary of the ecological attributes provided by each feeding guild in the terrestrial habitats on Burton Island is presented in **Table 5.2-2**. Assessment endpoints focus the ecological risk assessment on the feeding guild or community that might be affected adversely by exposure to a COPEC.

Assessment endpoints are selected for each mammal and bird feeding guild and each soil community. Assessment endpoints for guilds or communities reflect protection of one or more attributes of those receptors. In general, the assessment endpoints for this screening level ecological risk assessment include the following:

- Soil invertebrate survival, growth, and productivity;
- Terrestrial plant survival, growth, and productivity;
- Herbivore survival, growth, and productivity;
- Omnivore survival, growth, productivity;
- Invertivore survival, growth, productivity; and
- Carnivore survival, growth, productivity.

Soil invertebrates' survival, growth, productivity, and function as a decomposer are attributes in a terrestrial ecosystem that should be preserved. They provide a mechanism for the physical breakdown of detritus for microbial decomposition, which is also a vital function. Soil invertebrates also function as a major food source for omnivorous and invertivorous mammals and birds.

Terrestrial plants provide an important pathway for energy and nutrient transfer from soil to herbivorous (e.g., cottontail rabbit and whitetail deer) and omnivorous (mouse) receptors. Terrestrial plants also provide critically important habitat for terrestrial animals.

Herbivore survival, growth, and productivity are attributes to be protected in the terrestrial ecosystem because herbivores incorporate energy and nutrients from plants and transfer them to higher trophic levels. Herbivores are also integral to the success of terrestrial plants through such attributes as seed dispersal. Herbivores also serve as an important prey item for upper trophic level organisms.

Table 5.2-2

Assessment Endpoints for Terrestrial Habitats

Valued Ecological Entity	Representative Receptors	Ecological Attributes / Functional Roles
<u>Terrestrial Feeding Guilds :</u>		
Terrestrial Invertebrates	Nematodes, Gastropods, Oligochaetes, Arthropods	Soil invertebrates provide an important food source for many higher trophic level species. As decomposers and detritivores, they play a critical role in nutrient recycling. They also aid in soil aeration and infiltration by increasing macro- and micro-porosity.
Herbivorous Birds	Canada Goose, Bobwhite, Turkey, Dove	Herbivorous birds play an important role in seed dispersal and pollination for many types of terrestrial vegetation. They also play a role in egg dispersal for some invertebrate species. They are also an important prey item for higher trophic level predators.
Herbivorous Mammals	Eastern cottontail, Whitetail Deer, Gray Squirrel, Groundhog	Herbivorous mammals are an important prey item for many higher trophic level predators. They provide an important link for energy transfer between primary producers and higher trophic level consumers. In addition, these organisms play an important role in seed dispersal and plant pollination for many plant species.
Omnivorous Birds	American Robin, Blue Jay, American Crow, Cardinal	Omnivorous birds play an important role in seed dispersal and pollination for many types of terrestrial vegetation. They provide an important link for energy transfer between primary producers and higher trophic level consumers. They also provide egg dispersal for some invertebrate species. They are also an important prey item for higher trophic level predators.
Omnivorous Mammals	White-footed Mouse, Opossum, Raccoon, Woodrat	Omnivorous mammals are an important prey item for many higher trophic level predators. They provide an important link for energy transfer between primary producers and higher trophic level consumers. In addition, these organisms play an important role in seed dispersal and plant pollination for many plant species.
Invertivorous Birds	American Woodcock, House Wren, Northern Mockingbird, Killdeer	Invertivorous birds play an important role in the terrestrial environment by regulating invertebrate populations through predation. They also provide egg dispersal for some invertebrate species. They are also an important prey item for higher trophic level predators.
Invertivorous Mammals	Short-tailed Shrew, Skunk, Mole	Invertivorous mammals are an important prey item for many higher trophic level predators. They play an important role by regulating invertebrate populations through predation.
Carnivorous Birds	Red-Tailed Hawk, Black Vulture, Great Horned Owl, Kestrel	Carnivorous birds perform an important functional role in the environment by regulating lower trophic level prey populations and by scavenging carrion.

Omnivore survival, growth, and productivity are attributes to be protected because omnivores incorporate energy and nutrients from lower trophic levels and transfer them to higher levels. Many of the omnivorous species also serve as food sources for carnivorous species.

Invertivore survival, growth, and productivity are attributes worthy of protection because invertivorous birds and mammals play an important ecological role by regulating invertebrate populations through predation. Invertivores are also an important prey item for higher trophic level organisms.

Carnivore survival, growth, and productivity are attributes to be protected because carnivores provide food for other carnivores, omnivores, scavengers, and microbial decomposers. They also affect abundance, reproduction, and recruitment of lower trophic levels, such as vertebrate herbivores and omnivores, through predation.

Surrogate receptor species are selected to represent the various feeding guilds occupying the habitats within OU2 based on their ecological relevance, their sensitivity to COPECs, and the availability of natural history information. Terrestrial vegetation and soil invertebrates are evaluated as receptor groups, rather than developing toxicity reference values (TRVs) for specific species.

5.2.3.5 Measurement of Effects

The measure of effect is the characteristic of the measurement receptor used to evaluate the response of the attribute of the guild or community. A measurement endpoint (measurement of effect) includes a measurement receptor and its response to a COPEC media concentration or COPEC dose. The measure of effect is a measurable ecological characteristic that is related to the valued attribute selected as the assessment endpoint. The response of the receptor characteristic to a COPEC media concentration or dose is used to evaluate whether the assessment endpoint attribute is adversely affected by exposure to COPECs in environmental media.

5.2.3.5.1 Measures of Effect for Soil Communities

The responses to media concentrations of COPECs in soil are assessed by evaluating the potential for direct exposure and uptake to the soil invertebrate community and the terrestrial plant community.

Measured COPEC concentrations in surface soil are used to estimate potential risks to soil measurement receptors through direct comparison with standards and/or criteria for soil. These criteria are referenced from the scientific literature and are identified in Section 5.2.5 as applicable.

5.2.3.5.2 Measures of Effect for Upper Trophic Level Receptors

The response to a daily dose of COPEC to the most sensitive endpoint of a measurement receptor is the measure of effect for evaluating the potential hazard through direct and indirect exposure, for mammals and birds in each habitat-specific food web. Measurement receptors are identified for each mammal and bird feeding guild identified in the simplified food web (**Figure 5.2-1**). Reptiles and amphibians are not directly assessed in the food web models "because of the paucity of toxicological information on these receptors" (USEPA, 1999) and the lack of bio-uptake factors and models for amphibians and reptiles (Suter, et al., 2000). The measurement receptors have been selected to be representative of other species within the feeding guild, with respect to the guild's role in the ecosystem. The following factors were evaluated in the selection of measurement receptors:

- **Ecological Relevance:** Highly relevant receptors provide an important functional or structural aspect to the ecosystem. Attributes of highly relevant receptors fall under the categories of food, habitat, production, seed dispersal, pollination, and decomposition.

- **Exposure Potential:** Receptors with high exposure potential are those that, due to their metabolism, feeding habits, location, or reproductive strategy, tend to have higher potential for exposure than other receptors.

- **Sensitivity:** Highly susceptible receptors include those with low tolerances to COPECs as well as receptors with enhanced COPEC susceptibility due to other concomitant stressors that may not be related to COPECs, such as reduced habitat availability.

- **Social or Economic Importance:** These types of receptors include species valued for economic importance and threatened and endangered species. For these receptors, critical attributes include those that affect survival, production, and fecundity characteristics.

- **Availability of Natural History Information:** Natural history information is essential to quantitatively evaluate risks to measurement receptors. If information such as body weight, food, water, and soil ingestion rate is unavailable for a receptor, then another representative receptor species will be selected to represent a specific guild.

- **Habitat:** A measurement receptor must occupy a habitat type that is potentially impacted by ash material from the Ash Site. Measurement receptors will not be considered if their preferred habitat is not potentially impacted by ash material or if their preferred habitat does not occur within OU2.

- **Diet:** A measurement receptor must be exposed to ash material through ingestion of potentially impacted dietary items or through direct contact. Measurement receptors will only be considered if their diet consists of prey or other dietary items that have the potential to be impacted by ash material.

- **Availability of Toxicity Data:** A measurement receptor must have toxicity data available for the identified COPECs. If toxicity data is not available for a certain measurement receptor, then another representative receptor species will be selected to represent a specific guild.

Thus, receptor species have been selected to represent each feeding guild in the terrestrial food web described previously, based on the criteria listed above. These representative receptor species act as surrogates for all of the species occupying their respective feeding guilds. As such, this screening level ecological risk assessment assesses the risks to potentially exposed feeding guilds and not specific species.

Following the procedures presented in the previous paragraphs, surrogate measurement receptors were selected for the terrestrial habitats within OU2. Receptors characterized in USEPA's *Wildlife Exposure Factors Handbook* (USEPA, 1993) were evaluated to determine if they were suitable measurement receptors for feeding guilds identified in the terrestrial food web. If receptor species characterized in the *Wildlife Exposure Factors Handbook* (USEPA, 1993) were not suitable, then other receptors were selected and natural history information was gathered from available literature sources.

For characterizing potential risk to mammalian and avian feeding guilds, this assessment assumed that ingestion is the dominant exposure route; both direct ingestion of affected media (e.g. ingestion of soil) and indirect exposure through ingestion of affected food items. As is standard practice in most ecological risk assessments, inhalation and dermal uptake were not evaluated quantitatively in this assessment due to a general lack of appropriate exposure and toxicity data.

The surrogate species that have been identified as representative of the various feeding guilds operational within OU2 are summarized in **Table 5.2-3**.

Table 5.2-3

Representative Surrogate Species for Feeding Guilds Within OU2

Feeding Guild	Surrogate Species
Herbivorous Bird	Canada Goose (*Branta canadensis*)
Herbivorous Mammal	Eastern Cottontail (*Sylvilagus floridanus*)
Small Omnivorous Mammal	White-Footed Mouse (*Peromyscus leucopus*)
Omnivorous Bird	American Robin (*Turdus migratorius*)
Invertivorous Mammal	Short-Tailed Shrew (*Blarina brevicauda*)
Invertivorous Bird	American Woodcock (*Scolopax minor*)
Large Omnivorous Mammal	Red Fox (*Vulpes vulpes*)
Carnivorous Bird	Red-Tailed Hawk (*Buteo jamaicensis*)

5.2.4 Analysis

The analysis phase of this SLERA includes the characterization of ecological effects and the exposure assessment.

5.2.4.1 Characterization of Ecological Effects

The effects of COPECs on measurement endpoint receptors are evaluated through the comparison of exposure levels (media concentrations or doses) to toxicity reference values (TRVs). TRVs are biased toward over-protection of measurement endpoint receptors. All TRVs represent chronic NOAELs. TRVs are derived from data obtained from the scientific literature for terrestrial vegetation, soil macroinvertebrates, aquatic species, sediment (benthic) organisms, birds, and mammals. Because of the extremely limited toxicity data set for reptiles and amphibians, they are not quantitatively evaluated as receptor species.

In general there are two types of TRVs:

- Media-based TRVs for organisms inhabiting soil; and
- Dietary exposure-based TRVs for upper trophic level consumers (birds and mammals).

Media-based TRVs are usually based on screening values such as federal and state standards and are designed to be conservative. They are usually expressed as a concentration of COPEC per unit of media such as mg/kg of soil. TRVs for upper trophic level receptors are usually developed from laboratory toxicity tests in which a test organism is exposed to one or more chemical concentrations or doses for a specified period of time. They are usually expressed as COPEC dose ingested and normalized to receptor body weight (mg COPEC/kg body weight/day).

The following criteria were used to select toxicity data:

1) Chronic NOAEL;
2) Subchronic NOAEL;
3) Chronic LOAEL;
4) Subchronic LOAEL;
5) Acute median lethality point estimate; and
6) Single dose toxicity value.

Uncertainty factors (UFs) were used to extrapolate toxicity test data to TRVs where appropriate. The following UFs (Calabrese and Baldwin, 1993) were used to convert toxicity test endpoints to equivalent chronic NOAEL TRVs:

- Chronic LOAEL or LOAEL will be multiplied by a UF = 0.1 to convert to a chronic NOAEL;
- Subchronic NOAELs will be multiplied by a UF = 0.1 to convert to a chronic NOAEL;
- Acute lethal values (e.g., LD_{50}) will be multiplied by a UF = 0.01 to convert to a chronic NOAEL.

5.2.4.1.1 TRVs for Community Level Effects

Adverse effects to terrestrial vegetation and terrestrial invertebrates are evaluated in this assessment by comparing the estimated surface soil concentrations of COPECs to soil TRVs for the protection of terrestrial plants and terrestrial invertebrates. Specific TRVs for soil community level effects are identified in Section 5.2.5 as applicable.

5.2.4.1.2 TRVs for Upper Trophic Level (Birds and Mammals) Organisms

To evaluate potential food chain transfer of COPECs, TRVs for ingestion exposures are derived from the scientific literature for mammalian and avian species representing the guilds described in the terrestrial food web. The majority of the TRVs used in this assessment are those presented in Appendix E of USEPA's *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (USEPA, 1999). Supplementary toxicity information is referenced from *Toxicological Benchmarks for Wildlife: 1996 Revision* (Sample, et. al., 1996) and the IRIS (USEPA, 2010). The NOAEL-based TRVs from all of these sources for mammalian species of wildlife have been estimated from studies conducted primarily on laboratory rodents. The NOAEL-based benchmarks referenced in all of these sources for avian species have been estimated from studies on domestic and wild birds.

It is important to note that species-specific TRVs are not derived for this assessment; rather TRVs are derived for mammalian and avian receptors in general. Current scientific consensus is that there is considerable uncertainty in the derivation of species-specific TRVs and that generic TRVs applicable to mammalian and avian receptors in general are more appropriate for use in risk assessments. The TRVs for avian and mammalian receptors are identified in Section 5.2.5 as applicable.

5.2.4.2 Exposure Assessment

The objective of the exposure assessment is to quantify an estimate of direct and indirect exposure by a measurement receptor to site-related COPECs. COPEC exposures are assessed by determining the EPC for each measurement receptor and comparing it to a corresponding TRV. EPCs were determined based on the results of environmental sampling conducted at OU2 as described in previous chapters of this report.

5.2.4.2.1 Direct Exposures

For surface soil communities potentially impacted by direct exposure to COPECs in abiotic media, COPEC media concentrations are used to characterize exposure to measurement receptors in the various habitats. Direct exposures of soil communities to COPECs in surface soil are quantified by simply estimating the EPC of the COPECs in surface soil.

Terrestrial plant and soil invertebrate direct exposures to the COPECs in soil are summarized in **Table 5.2-4**. In addition to the information provided in **Table 5.2-1** (e.g., maximum detected concentration, average concentration), this table also provides an estimate of the exposure point concentration for each COPEC. The EPC is the average concentration to which the ecological receptors are likely exposed. Since the average concentration can only be estimated based on the samples that were collected, a conservative estimate of the average concentration is used as the exposure point concentration. This conservative estimate is the 95^{th} percentile UCL on the average concentration. Several steps were necessary to determine the UCL concentrations.

Table 5.2-4

Community-Level Ecological Hazard Assessment

Surface Soil COPEC	EPC (mg/kg)	Terrestrial Plant ESV (mg/kg)	Terrestrial Plant HQ	Terrestrial Invertebrate ESV (mg/kg)	Terrestrial Invertebrate HQ
Arsenic	150	18 [a]	8.33	60 [c]	2.5
Barium	526	500 [b]	1.05	330 [a]	1.59
Mercury	0.558	0.3 [b]	1.86	0.1 [c]	5.58
Nickel	37.1	38 [a]	0.98	280 [a]	0.13
Selenium	4.3	0.52 [a]	8.27	4.1 [a]	1.05
Thallium	1.58	1 [b]	1.58	NA	NC

Notes:
COPEC – constituent of potential ecological concern
EPC – exposure point concentration
ESV – ecological screening value
HQ – hazard quotient
mg/kg – milligrams per kilogram.
NA – Not Available
NC – Not Calculated
[a] USEPA Eco-SSLs
[b] Efroymson, et al. (1997a). Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.
[c] Efroymson, et al. (1997b). Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision.

The first step was to determine the appropriate statistical distribution (i.e., normal, log-normal, other) that the data represented. This was accomplished by using the W-test or D'Agostino's Test depending on the size of the data set (Gilbert 1987). The W-test was developed by Shapiro and Wilk (1965) and is used for testing whether a data set is from a normal distribution. By conducting the test on the log-transformed data, it is equally effective for testing whether a data set is from a log-normal distribution. The W-test is used for data sets with fewer than 50 data points. D'Agostino's test (D'Agostino 1971) is used for testing for normality or log-normality for data sets with greater than fifty elements. For normal and log-normal distributions, the UCL was calculated according to the following equations. For normal distributions:

$$UCL = x + t\left(s \big/ \sqrt{n} \right)$$

where:

UCL = upper confidence limit*x*
= mean of the un-transformed data*s*
= standard deviation of the un-transformed data*t*
= Student-t statistic*n*
= number of samples.

For log-normal distributions:

$$UCL = e^{\left(x + 0.5s^2 + sH / \sqrt{n-1}\right)}$$

where:

UCL	=	upper confidence limitx
	=	mean of the transformed datas
	=	standard deviation of the transformed dataH
	=	H-statisticn
	=	number of samples.

In accordance with USEPA guidance (Singh, et al., 1997), the non-parametric jackknife method was used to determine the 95 percent UCL for any data that were not identified as either normal or log-normal. The jackknife procedure requires no assumptions regarding the statistical distribution. The procedure is conceptually simple and is based on re-sampling techniques that tend to require considerable computing power. For a data set of size n, n estimates of the mean are computed by deleting one observation at a time from the data set. The jackknife estimate of the mean and the standard deviation can be calculated to reduce the bias in the data set, and appropriate confidence limits can be derived (see Singh et al. [1997] for mathematical details). For small data sets (those with fewer than 10 samples), the maximum detected concentration is used if the calculated 95 percent UCL exceeds the maximum detected concentration. The 95 percent UCL was calculated for each of the data sets used as a conservative estimate of the true average concentration for that media that the data set represents. In the case that the calculated 95 percent UCL is greater than the maximum detected concentration, the maximum detected concentration was used instead of the calculated 95 percent UCL.

For the calculation of both average and 95 percent UCL concentrations, samples with non-detectable levels were considered to contain half of the detection limit of that constituent. In cases where samples with non-detectable levels had detection limits greater than the detected concentrations in all other samples, the data were not used in the calculation of 95 percent UCLs. **Table 5.2-1** presents the EPCs for each of the COPECs identified in surface soil. This table includes the statistical method used to determine the 95 percent UCL depending on the statistical distribution, if any, that fits the data, the 95 percent UCL and the arithmetic average concentration.

5.2.4.2.2 Indirect Exposures

Indirect exposures are assessed via dietary exposure (food web) modeling and are performed for bird and mammal feeding guilds. As is the case with direct exposures, media and food concentrations of COPECs used in the indirect exposure assessments are estimated based on the results of the soil sampling that was conducted as part of the RI for OU2. Quantification of indirect exposures used the same exposure point concentrations that were estimated for the direct exposures as described in the previous section. Therefore, the indirect exposures estimated in this assessment are applicable to exposures that may occur on or adjacent to the Ash Site and are also protective of exposures that could potentially occur in other habitats in the vicinity of the Ash Site. Using measured COPEC concentrations in surface soil, concentrations of COPECs are estimated in terrestrial plants, terrestrial invertebrates, and prey animal tissues. These COPEC tissue concentrations are used to estimate food web transfers to higher trophic levels. Dietary exposures of higher trophic level organisms (birds and mammals) are compared to TRVs to estimate potential ecological risks.

A COPEC daily dose (DD) for a mammal or bird feeding guild is a measure of the daily mass of COPEC ingested from plant and animal matter, and the daily mass of COPEC ingested from abiotic media. The DD for each mammal and bird feeding guild is calculated using natural history information for the corresponding surrogate measurement receptor. The generic equation for calculating DD for each feeding guild is as follows:

$$DD = \sum \frac{IR_f \cdot C_i \cdot P_i \cdot F_i \cdot AUF}{BW} + \sum \frac{IR_m \cdot C_m \cdot P_m \cdot AUF}{BW}$$

where:

DD	=	daily dose of COPEC ingested (mg COPEC/kg body weight/day);
IR_f	=	food ingestion rate (kg/day);
C_i	=	COPEC concentration in i^{th} food item (mg/kg);
P_i	=	proportion of food item *i* that is affected (unitless);
F_i	=	fraction of diet consisting of food item *i* (unitless);
AUF	=	area use factor (unitless);
BW	=	body weight of measurement receptor (kg);
IR_m	=	abiotic media ingestion rate (kg/day or l/day);
C_m	=	COPEC concentration in abiotic medium (mg/kg or mg/L); and
P_m	=	proportion of abiotic media that is affected (unitless).

The variables in the equation above are determined as follows:

- Food ingestion rates, media ingestion rates, and body weights are measurement receptor specific;
- Fraction of a measurement receptor diet consisting of a particular food item depends on the number of guilds from which a measurement receptor feeds. Exposures from all appropriate dietary components are summed in exposure modeling;
- COPEC concentrations in terrestrial plant tissue depend on the COPEC concentration in soil and the corresponding soil-to-plant bioaccumulation factor ($BAF_{soil\text{-}plant}$);
- COPEC concentrations in terrestrial invertebrates depend on the soil concentration and the corresponding soil-to-invertebrate BAF ($BAF_{soil\text{-}invert}$);
- COPEC concentrations in mammals and birds (prey) ingested by other mammals and birds are prey-specific, depending on the trophic level of the prey;
- AUF is dependent upon the receptor species used as a surrogate for a given feeding guild;
- Proportion of ingested food and abiotic media that is affected will be assumed to be 100 percent; and
- COPEC concentrations in ingested abiotic media are assumed to be constant.

The natural history parameters for the surrogate species used in the food web modeling are presented in **Table 5.2-5** for the terrestrial food web model. The methods for estimating COPEC concentrations in the various abiotic media and food items utilized in the food web models are described below.

It is important to note that there are different BAF for mercuric chloride and methyl-mercury as these two forms of mercury have different fate and transport properties and elicit different toxicological responses. Since soil samples were only analyzed for total recoverable mercury, the exact speciation of the detected mercury in the environmental samples is unknown. Per USEPA (1999) guidance, "in soil, 98 percent of total mercury is assumed to be divalent mercury

Table 5.2-5

Terrestrial Food Web Indicator Species Life History Parameters

Common Name	Scientific Name	Feeding Guild	Foraging Area [a] (Ha)	Body Weight [a] (kg)	Water Intake [a] (L/day)	Food Intake [a] (kg/day-dry wt.)	Soil / Sediment Intake [a] (kg/day-dry wt.)	Dietary Fraction	Dietary Component
Canada Goose	*Branta canadensis*	Herbivorous Bird	983	1.362	0.072	0.0203	0.0017	1.0	Terrestrial Vegetation
Eastern Cottontail	*Sylvilagus floridanus*	Herbivorous Mammal	3.13	1.132	0.1098	0.0157	0.00099	1.0	Terrestrial Vegetation
White-Footed Mouse	*Peromyscus leucopus*	Omnivorous Mammal	0.049	0.0148	0.0028	0.00129	0.00003	0.5	Terrestrial Invertebrates
								0.5	Terrestrial Vegetation
American Robin	*Turdus migratorius*	Omnivorous Bird	0.25	0.0773	0.0108	0.02969	0.00297	0.5	Terrestrial Invertebrates
								0.5	Terrestrial Vegetation
Short-Tailed Shrew	*Blarina brevicauda*	Invertivorous Mammal	0.39	0.015	0.0033	0.00133	0.00003	1.0	Terrestrial Invertebrates
American Woodcock	*Scolopax minor*	Invertivorous Bird	24.8	0.1338	0.0134	0.0165	0.00172	1.0	Terrestrial Invertebrates
Red Fox	*Vulpes fulva*	Omnivorous Mammal	923	3.94	0.3349	0.1318	0.00369	0.1	Terrestrial Vegetation
								0.1	Terrestrial Invertebrates
								0.4	Herbivorous Prey
								0.4	Omnivorous Prey
Red-Tailed Hawk	*Buteo jamaicensis*	Carnivorous Bird	842	0.957	0.0545	0.0302	0.00060	0.5	Herbivorous Prey
								0.5	Omnivorous Prey

[a] USEPA, 1993. Wildlife Exposure Factors Handbook. USEPA/600/R-93/187a

[b] Omnivorous Prey are modeled as white-footed mouse for this assessment

IR_F = 0.00666 kg/day

IR_W = 0.0028 l/day

IR_{SO} = 0.000113 kg/day

[c] Herbivorous Prey are modeled as eastern cottontail for this assessment

IR_F = 0.0958 kg/day

IR_W = 0.1098 l/day

IR_{SO} = 0.00958 kg/day

Ha – hectares.

kg – kilogram.

L/day – Liters per day.

kg/day-dry wt. – kilograms per day on a dry weight basis.

and the remaining mass as methyl mercury." Therefore, for this assessment it was assumed that 98 percent of the total measured mercury in surface soil samples was divalent mercury and the remaining 2 percent was assumed to be methyl mercury.

Concentrations of COPECs in Terrestrial Plants.

The COPEC concentrations in terrestrial plant matter were estimated using literature-based soil-to-plant bioaccumulation factors ($BAF_{soil\text{-}plant}$) for the soil COPECs. These $BAF_{soil\text{-}plant}$ were applied to the measured soil concentrations of COPECs to estimate concentrations of COPECs in terrestrial vegetative food material in the following manner:

$$C_{tp} = C_{soil} \times BAF_{soil-plant}$$

where:

C_{tp}	=	COPEC concentration in terrestrial plants (mg/kg-dry weight);
C_{soil}	=	COPEC concentration in soil (mg/kg-dry weight); and
$BAF_{soil\text{-}plant}$	=	soil-to-plant bioaccumulation factor (unitless).

The $BAF_{soil\text{-}plant}$ values were referenced from the *USEPA's Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (1999).

Concentrations of COPECs in Terrestrial Invertebrates.

COPEC concentrations in terrestrial invertebrate tissues were estimated by applying empirically-derived soil-to-earthworm bioaccumulation factors ($BAF_{soil\text{-}invert}$). These $BAF_{soil\text{-}invert}$ have been developed from field data for selected inorganics and reported in the USEPA's *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (1999). These $BAF_{soil\text{-}invert}$ were applied to the measured soil concentrations of COPECs to estimate concentrations of COPECs in terrestrial invertebrate food material in the following manner:

$$C_{invert} = C_{soil} \times BAF_{soil-invert}$$

where:

C_{invert}	=	COPEC concentration in terrestrial invertebrates (mg/kg-dry weight);
C_{soil}	=	COPEC concentration in soil (mg/kg-dry weight); and
$BAF_{soil\text{-}invert}$	=	soil-to-invertebrate bioaccumulation factor (unitless).

Prey species will be exposed to COPECs through ingestion of abiotic media, such as from foraging and preening (direct uptake), and through ingestion of COPEC-affected food (indirect uptake). Exposure from direct uptake will be estimated using an abiotic medium-to-herbivore BCF. Exposure from indirect uptake will be estimated using a plant-to-herbivore BCF_{P-H} for plant ingestion and a biomagnification factor for the animal ingestion pathway. These methods are described below.

***Concentrations of COPECs in Herbivorous Prey*.**

Herbivores are trophic level two (TL2) consumers of plant matter. The COPEC concentration in a herbivorous prey species depends on the proportion of abiotic media and plant material ingested. The general equation for calculating COPEC concentrations in herbivorous prey species is as follows:

$$C_H = \sum \left(C_P \cdot BCF_{P-H} \cdot P_P \cdot F_P\right) + \left(C_S \cdot BCF_{S-H} \cdot P_S\right)$$

where:

C_H	=	COPEC concentration in herbivorous prey (mg/kg);
C_P	=	COPEC concentration in plant tissue (mg/kg);
BCF_{P-H}	=	plant-to-herbivore bioconcentration factor (unitless);
P_P	=	proportion of plant that is affected (unitless);
F_P	=	fraction of diet comprised of plant species (unitless);
C_S	=	COPEC concentration in surface soil (mg/kg);
BCF_{S-H}	=	soil-to-herbivore bioconcentration factor (unitless); and
P_S	=	proportion of soil in diet that is affected (unitless).

Plant-to-herbivore BCFs are used to estimate COPEC exposure from ingestion of plant material. Media-to-herbivore BCFs are used to estimate COPEC exposure from ingestion of abiotic media. These BCFs are receptor-specific and COPEC-specific and are determined from biotransfer factors as discussed below.

***Concentrations of COPECs in Omnivorous Prey*.**

Omnivores are trophic level three (TL3) consumers of plant and animal matter. In order to estimate COPEC concentrations in omnivorous prey tissues, a food chain multiplier (FCM) is applied to each plant food item to account for bioaccumulation of a COPEC in the omnivore due to ingestion of plant material. A ratio of FCMs is applied to each animal food item to account for the increase in COPEC concentration occurring between the trophic level of the prey item (TLn) and the trophic level of the omnivore (TL3).

The COPEC concentration in omnivorous prey species depends on the COPEC concentrations in each food item, the trophic level of each food item, and the COPEC concentration in abiotic media as described in the following equation:

$$C_O = \sum\left(C_A \cdot \frac{FCM_{TL3}}{FCM_{TLn}} \cdot P_A \cdot F_A\right) + \sum\left(C_P \cdot BCF_{P-O} \cdot P_P \cdot F_P\right) + \left(C_S \cdot BCF_{S-O} \cdot P_S\right)$$

where:

C_o	=	COPEC concentration in omnivorous prey (mg/kg);
C_A	=	COPEC concentration in animal food item (mg/kg);
FCM_{TL3}	=	food chain multiplier for trophic level 3 (unitless);
FCM_{TLn}	=	food chain multiplier for trophic level of animal food item (unitless);
P_A	=	proportion of animal food item that is affected (unitless);
F_A	=	fraction of diet that is composed of animal prey item (unitless);
C_P	=	COPEC concentration in plant food item (mg/kg);
BCF_{P-O}	=	plant-to-omnivore bioconcentration factor (unitless);
P_P	=	proportion of plant food item that is affected (unitless);
F_P	=	fraction of diet that is composed of plant item (unitless);
C_S	=	COPEC concentration in soil (mg/kg);
BCF_{S-O}	=	soil-to-omnivore bioconcentration factor (unitless); and
P_S	=	proportion of soil that is affected (unitless).

A plant-to-omnivore BCF is used to estimate COPEC exposure from ingestion of plant material. Media-to-omnivore BCFs are used to estimate COPEC exposure from ingestion of abiotic media. These BCFs are receptor-specific and COPEC-specific and are determined from biotransfer factors, as discussed below. The use of a FCM ratio to estimate potential for biomagnification from ingestion of COPEC-affected animal matter is also discussed below.

Bioconcentration Factors.

BCFs for estimating COPEC concentrations in upper trophic level prey species are calculated from biotransfer factors (BTF) for beef cattle (Ba_{beef}) and domestic chickens (Ba_{chick}). Inorganic BTFs are referenced from Baes, et. al., (1984). BTFs are also presented in the Draft USEPA Guidance (1999). Abiotic media-to-wildlife and plant-to-herbivore BCFs are calculated for each upper trophic level consumer according to the following equation:

$$BCF_{M-W} = BTF \cdot FIR$$

where:

BCF_{M-W}	=	abiotic media-to-wildlife bioconcentration factor (unitless);
BTF	=	chicken or beef biotransfer factor (day/kg food); and
FIR	=	upper trophic level consumer food ingestion rate (kg/day).

Food Chain Multipliers.

The use of a FCM is a mechanism for estimating the potential for COPEC biomagnification through a food chain. COPECs with the highest potential for biomagnification are highly lipophilic, have low water solubilities, and are resistant to metabolic decomposition. FCMs have been developed by the USEPA for use in developing water quality criteria for piscivorous wildlife under the *Water Quality Guidance for the Great Lakes System* (USEPA, 1995). The USEPA-derived FCMs are used in this ecological risk assessment.

This screening level ecological risk assessment uses FCM ratios to estimate the potential increase in COPEC concentration resulting from upper trophic level consumers preying on lower trophic level prey. The potential for biomagnification is estimated by calculating the quotient of the FCM of the measurement receptor divided by the FCM of the prey in the following manner:

$$BMF = \frac{FCM_{TLn}}{FCM_{TLn-1}}$$

where:

BMF	=	potential biomagnification factor (unitless);
FCMTLn	=	food chain multiplier for trophic level n (unitless); and
FCMTLn-1	=	food chain multiplier for trophic level n-1 (unitless).

The fate and transport properties that determine the exposure point concentrations of COPECs are presented in **Table 5.2-6**. The exposure point concentrations in abiotic media and food items used in the terrestrial food web model are presented in **Table 5.2-7**.

***Soil ingestion Rates*.**

Many feeding guilds ingest soil during routine activities such as feeding, grooming, nest-building, etc. The soil ingestion rates for the receptor species are most often represented as a percentage of a receptor species' diet. The relationship used to estimate the soil ingestion rates for the various terrestrial feeding guilds assessed in the food web modeling is the following:

$$IR_{soil} = IR_{food} \times Diet_{soil}$$

where:

IR_{soil} = ingestion rate of soil (mg/kg/day-dry weight);

IR_{food} = ingestion rate of food (mg/kg/day-dry weight); and

$Diet_{soil}$ = portion of diet that is soil (percent).

Table 5.2-6

Biological Fate and Transport Properties for the Constituents of Potential Ecological Concern in the Terrestrial Food Web

Bioaccumulative Constituents of Potential Ecological Concern	CAS Number	Molecular Weight	Henry's Law Constant (atm/m^3-$mole^{-1}$)	Octanol-Water Partition Coefficient (log K_{ow}) (M_{oct}/M_{water})	Organic Carbon Partition Coefficient (log K_{oc}) (L/kg)	Soil to Plant BAF [b] (unitless)	Soil to Invertebrate BAF [b] (unitless)	Mammal Biotransfer Factor (BTF_{prey}) (day/kg)	Plant to Herbivorous Prey BCF (unitless)	Soil to Herbivorous Prey BCF (unitless)	Water to Herbivorous Prey BCF (unitless)	Plant to Omnivorous Prey BCF (unitless)	Soil to Omnivorous Prey BCF (unitless)	Water to Omnivorous Prey BCF (unitless)
Arsenic	7440-38-2	74.92	0.00E+00	NA	NA	0.036	0.11	2.00E-03 [a]	1.92E-04	1.92E-05	2.20E-04	6.66E-06	6.66E-06	6.66E-06
Barium	7440-39-3	137.33	0.00E+00	NA	NA	0.15	0.22	1.50E-04 [a]	1.44E-05	1.44E-06	1.65E-05	5.00E-07	5.00E-07	5.00E-07
Methyl Mercury	22967-92-6	216	4.70E-07	NA	NA	0.137	8.5	2.50E-01 [a]	2.40E-02	2.40E-03	2.75E-02	8.33E-04	8.33E-04	8.33E-04
Mercuric Chloride	7487-94-7	271.52	7.10E-10	-0.22	NA	0.0375	0.04	2.50E-01 [a]	2.40E-02	2.40E-03	2.75E-02	8.33E-04	8.33E-04	8.33E-04
Nickel	7440-02-0	58.69	0.00E+00	NA	NA	0.032	0.02	6.00E-03	5.75E-04	5.75E-05	6.59E-04	2.00E-05	2.00E-05	2.00E-05
Selenium	7782-49-2	78.96	0.00E+00	NA	NA	0.016	0.22	1.50E-02 [a]	1.44E-03	1.44E-04	1.65E-03	5.00E-05	5.00E-05	5.00E-05
Thallium	7440-28-0	204.38	0.00E+00	NA	NA	0.004	0.22	4.00E-02 [a]	3.83E-03	3.83E-04	4.39E-03	1.33E-04	1.33E-04	1.33E-04

[a] Baes, C.F., R.D. Sharp, A.L. Sjoreen and R.W. Shor, 1984, A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture, Prepared for the U.S. Department of Energy under contract No. DE-AC05-84OR21400.
[b] USEPA, 1999. Screening level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities.

Table 5.2-7

Exposure Point Concentrations for the Constituents of Potential Ecological Concern in the Terrestrial Food Web

Bioaccumulative Constituents of Potential Ecological Concern	Constituent Concentration					
	Surface Water (mg/L)	Soil (mg/kg)	Terrestrial Vegetation (mg/kg)	Terrestrial Invertebrates (mg/kg)	Omnivorous Prey (mg/kg)	Herbivorous Prey (mg/kg)
Arsenic	9.90E-03	1.50E+02	5.40E+00	1.65E+01	8.25E+00	3.39E-03
Barium	6.17E-02	5.26E+02	7.89E+01	1.16E+02	5.79E+01	1.32E-03
Methyl Mercury	ND	1.12E-02	1.53E-03	9.49E-02	4.74E-02	4.50E-05
Mercuric chloride	ND	5.47E-01	2.05E-02	2.19E-02	1.14E-02	1.56E-03
Nickel	5.00E-03	3.71E+01	1.19E+00	7.42E-01	3.72E-01	2.48E-03
Selenium	ND	4.30E+00	6.88E-02	9.46E-01	4.73E-01	6.67E-04
Thallium	ND	1.58E+00	6.32E-03	3.48E-01	1.74E-01	6.18E-04

The portions of the feeding guilds' diets that are soil are referenced from the USEPA's *Wildlife Exposure Factors Handbook* (USEPA, 1993) and are summarized in **Table 5.2-8**.

Table 5.2-8

Percent Soil in Diet of Feeding Guilds

Feeding Guild	Receptor Species	Percent Soil in Diet
Terrestrial Food Web:		
Herbivorous Bird	Canada Goose	8.2
Herbivorous Mammal	Eastern Cottontail	6.3
Omnivorous Mammal	White-Footed Mouse	2
Omnivorous Bird	American Robin	10
Invertivorous Mammal	Short-Tailed Shrew	2.4
Invertivorous Bird	American Woodcock	10.4
Omnivorous Mammal	Red Fox	2.8
Carnivorous Bird	Red-Tailed Hawk	2

Most wildlife food ingestion rates are presented in units of mg/kg/day wet weight. In order to convert these ingestion rates to dry weight, the moisture content of the wildlife species' diets must be known or approximated. The moisture contents of the food material in the receptor species' diets were referenced from the USEPA's *Wildlife Exposure Factors Handbook* (USEPA, 1993) and are as follows:

- Terrestrial Vegetation - 52%
- Terrestrial Invertebrates - 84%
- Herbivorous Prey - 68%
- Omnivorous Prey - 68%

The weighted-average moisture contents of the diets of the receptor species of interest are summarized in **Table 5.2-9**.

Table 5.2-9

Weighted-Average Moisture Contents of Diet of Receptor Species of Interest

Feeding Guild	Receptor Species	Weighted Average Moisture Content of Diet
Terrestrial Food Web:		
Herbivorous Bird	Canada Goose	52%
Herbivorous Mammal	Eastern Cottontail	52%
Omnivorous Mammal	White-Footed Mouse	68%
Omnivorous Bird	American Robin	68%
Invertivorous Mammal	Short-Tailed Shrew	84%
Invertivorous Bird	American Woodcock	84%
Omnivorous Mammal	Red Fox	68%
Carnivorous Bird	Red-Tailed Hawk	68%

Dietary composition of the indicator species was simplified for modeling purposes but incorporates the major food types for the different feeding guilds. It was assumed that food intake for invertivores is comprised almost entirely of terrestrial invertebrates (i.e., earthworms). It was also assumed that omnivores consume both plant and animal material, a portion of which consists of terrestrial invertebrates.

The AUFs for each of the indicator species take into account the home range and habitat requirements for each species and the size of the affected areas and potentially viable habitat at the Ash Site.

OU2 is approximately 93.6 acres in size. Using this upland area and the receptor species' home ranges, the AUF for each receptor species in the terrestrial food web was calculated. The results are listed in **5.2-10**.

The terrestrial food web model was executed with the aforementioned exposure point concentrations in order to estimate potential wildlife exposures. The food web model was executed with site-specific area use factors and literature-derived bioaccumulation factors. COPEC exposures for each feeding guild assessed in the terrestrial food web model are presented in **Tables N-1** through **N-8** in **Appendix N**.

Table 5.2-10

Area Use Factors for Feeding Guilds

Feeding Guild	*Receptor Species*	*Area Use Factor*
Terrestrial Food Web:		
Herbivorous Bird	Canada Goose	0.038
Herbivorous Mammal	Eastern Cottontail	1
Omnivorous Mammal	White-Footed Mouse	1
Omnivorous Bird	American Robin	1
Invertivorous Mammal	Short-Tailed Shrew	1
Invertivorous Bird	American Woodcock	1
Omnivorous Mammal	Red Fox	0.041
Carnivorous Bird	Red-Tailed Hawk	0.045

5.2.5 Risk Characterization

The risk characterization phase of the SLERA integrates the results of the ecological effects assessment and exposure assessment to determine the potential risks posed by COPECs to measurement endpoints. This SLERA calculates EHQs for each measurement receptor.

As described previously, there are two levels of assessment: potential ecological hazards from direct exposure and potential ecological hazards from indirect, or food web exposure. Direct exposure hazards are calculated by comparing the measured abiotic media COPEC concentrations (e.g., soil) to the COPEC-specific TRVs. Indirect exposure hazards are estimated by comparing the total daily dose of COPEC received by a given feeding guild to the COPEC-specific TRV. TRVs for food web exposures are reported as two different levels: the NOAEL, and the LOAEL, as defined below.

- ***No Observable Adverse Effect Level –*** The highest concentration or dose at and below which effects are not observed. Since all samples with COPEC concentrations or doses at or below the NOAEL have no observable effects, there is strong evidence that the COPEC is not toxic at levels at or below the NOAEL under those environmental conditions.

- ***Lowest Observable Adverse Effect Level –*** The lowest concentration or dose at which an adverse effect is observed. Often some samples with concentrations or doses between the LOAEL and NOAEL are toxic and other samples are not toxic. The LOAEL is the lowest concentration or dose of the COPEC in this range that has an observed adverse effect. Since some COPEC concentrations or doses above the LOAEL are not toxic, the evidence that the COPEC is the cause of the observed effect is not as strong. The effects may or may not be related to the COPEC.

Ecological hazards for community-level receptors at OU2 were estimated by calculating EHQs for each COPEC in soil. Community-level EHQs were estimated via the following relationship:

$$EHQ_{comm} = \frac{EPC}{TRV_{comm}}$$

where:

EHQcomm = *community-level ecological hazard quotient (unitless);*
EPC = *exposure point concentration (mg/kg); and*
TRVcomm = *community-level toxicity reference value (mg/kg).*

Ecological hazards for higher trophic level organisms that could potentially be exposed to ash material through food web interactions were estimated by calculating EHQs for each COPEC in the terrestrial ecosystem. These indirect exposure EHQs were estimated via the following relationship:

$$EHQ_{web} = \frac{TDD}{TRV_{web}}$$

where:

EHQ_{web} = ecological hazard quotient for food web receptors (unitless);
TDD = total daily dose of COPEC ingested by surrogate species (mg/kg-day); and
TRV_{web} = toxicity reference value for mammalian or avian receptor species (mg/kg-day).

A calculated EHQ equal to or less than one indicates the exposure point concentration or total daily dose is equal to or less than the chemical's conservative TRV and is interpreted in this assessment as a constituent that is not likely to pose the potential for adverse ecological risk. Conversely, an EHQ value greater than one indicates that the exposure point concentration or total daily dose is greater than the TRV and that the chemical might pose adverse ecological hazards to one or more receptors and requires further assessment.

5.2.5.1 Characterization of Soil Community Risks

Soil communities assessed in this ecological risk assessment include terrestrial plants and terrestrial invertebrates. As discussed previously, plant communities and terrestrial invertebrate communities were assessed by comparing estimated soil exposure point concentrations to TRVs for the protection of terrestrial plants and terrestrial invertebrates. The EHQ values for the COPECs identified in surface soil at OU2 are shown in **Table 5.2-11**.

Table 5.2-11

EHQ Values for the COPECs in Surface Soil

Surface Soil COPEC	**EPC** (mg/kg)	**Terrestrial Plant ESV** (mg/kg)	**Terrestrial Plant HQ**	**Terrestrial Invertebrate ESV** (mg/kg)	**Terrestrial Invertebrate HQ**
Arsenic	150	18	8.33	60	2.5
Barium	526	500	1.05	330	1.59
Mercury	0.558	0.3	1.86	0.1	5.58
Nickel	37.1	38	0.98	280	0.13
Selenium	4.3	0.52	8.27	4.1	1.05
Thallium	1.58	1	1.58	NA	NC

COPEC – constituent of potential ecological concern
EPC – exposure point concentration
ESV – ecological screening value
HQ – hazard quotient
mg/kg – milligrams per kilogram

The soil EPCs for arsenic, barium, mercury, selenium, and thallium exceed their respective terrestrial plant and terrestrial invertebrate screening values.

The terrestrial plant ESV for arsenic is referenced from the Eco-SSL for arsenic (USEPA, 2005a) and is the geometric mean of the maximum acceptable toxicant concentration (MATC) values reported for each of the three test species (ryegrass, cotton, and rice) evaluated by USEPA under two separate test conditions (pH and percent organic matter) and is equal to 18 mg/kg. All 14 surface soil samples exhibited arsenic concentrations greater than the terrestrial plant ESV. USEPA has not developed an arsenic Eco-SSL for terrestrial invertebrates, but Efroymson, et al., (1997b) provide a soil invertebrate screening benchmark of 60 mg/kg based on effects to both growth and reproduction in earthworms. Twelve of the 14 surface soil samples exhibited arsenic concentrations that exceeded the terrestrial invertebrate ESV.

USEPA has not developed an Eco-SSL for terrestrial plants and barium; however, the terrestrial plant screening benchmark provided by Efroymson et al. (1997a) is given as 500 mg/kg based on a reduction in shoot length of barley plants. Five surface soil samples exhibited barium concentrations that exceeded the terrestrial plant ESV. The ESV for barium and terrestrial invertebrates is the Eco-SSL (USEPA, 2005b) and is the geometric mean of the 20-percent effective concentration (EC_{20}) values reported for each of three test species (pot worm, springtail, earthworm) under three separate test conditions of pH, and is equal to 330 mg/kg. Eleven surface soil samples exhibited barium concentrations that exceeded the terrestrial invertebrate ESV.

USEPA has not developed Eco-SSLs for mercury. The terrestrial plant ESV of 0.3 mg/kg (Efroymson et al., 1997a) is based on effects on plants in surface soil at this concentration of mercury. Inorganic mercury does not translocate within plants to any great extent though organic forms of mercury (e.g. methyl mercury, usually present in much lower concentrations) may translocate to a higher degree in some plants. Twelve surface soil samples exhibited mercury concentrations in exceedance of the mercury ESV for terrestrial plant. Efroymson et al. (1997b) have developed an ESV for mercury based on an LOEC of 0.5 mg/kg (survival and cocoon production in earthworms) and a safety factor of 5 resulting in a soil invertebrate screening benchmark of 0.1 mg/kg. All 14 surface soil samples exhibited mercury concentrations that exceeded the terrestrial invertebrate ESV.

The terrestrial plant ESV for nickel is the Eco-SSL (USEPA, 2007c) protective of terrestrial plants (38 mg/kg). The Eco-SSL is the geometric mean of the MATC and EC_{20} values for 6 species under different test conditions (pH and percent organic matter). Three surface soil samples exhibited nickel concentrations that exceeded the terrestrial plant ESV; however, the calculated exposure point concentration of nickel was less than the terrestrial plant ESV. The terrestrial invertebrate ESV for nickel is the Eco-SSL (USEPA, 2007c) protective of terrestrial invertebrates (280 mg/kg). The ESV is based on the geometric mean of the MATCs for five species under different test conditions (pH and percent organic matter) and is equal to 280 mg/kg. All of the surface soil samples exhibited nickel concentrations less than the terrestrial invertebrate ESV.

The terrestrial plant ESV for selenium is the Eco-SSL (USEPA, 2007d) protective of terrestrial plants (0.52 mg/kg). The Eco-SSL is the geometric mean of the MATC and EC_{20} values for 6 species under different test conditions (pH and percent organic matter). All 14 surface soil samples exhibited selenium concentrations greater than the terrestrial plant ESV. The terrestrial invertebrate ESV for selenium is the Eco-SSL (USEPA, 2007d) protective of terrestrial invertebrates (4.1 mg/kg). The terrestrial invertebrate Eco-SSL is the geometric mean of the EC_{20} values for three test species (earthworm, springtail, and Enchytraeidae). Three surface soil samples exhibited selenium concentrations greater than the terrestrial invertebrate ESV.

The USEPA has not developed Eco-SSLs for thallium. The terrestrial plant ESV for thallium (1.0 mg/kg) is referenced from Efroymson, et al. (1997a) and is based on unspecified toxic effects on plants grown in soil with 1 ppm thallium. Twelve surface soil samples exhibited thallium concentrations greater than the terrestrial plant ESV. Terrestrial invertebrate ESVs for thallium were not found in the literature.

Surface soil samples collected from OU2 exhibit concentrations of arsenic, barium, mercury, selenium, and thallium that may have the potential to adversely affect plants and soil invertebrates.

5.2.5.2 Characterization of Upper Trophic Level Risks

Upper trophic level feeding guilds in the terrestrial habitats within OU2 were assessed in this SLERA via a terrestrial food web model. The terrestrial food web model utilized surrogate receptor species to represent the different feeding guilds that utilize the Ash Site for feeding, nesting, and other normal activities. The feeding guilds and their representative surrogate species assessed in the terrestrial food web model are listed in **Table 5.2-3** copied again here for ease of reference.

Table 5.2-3

Representative Surrogate Species for Feeding Guilds

Feeding Guild	Surrogate Species
Herbivorous Bird	Canada Goose (*Branta canadensis*)
Herbivorous Mammal	Eastern Cottontail (*Sylvilagus floridanus*)
Small Omnivorous Mammal	White-Footed Mouse (*Peromyscus leucopus*)
Omnivorous Bird	American Robin (*Turdus migratorius*)
Invertivorous Mammal	Short-Tailed Shrew (*Blarina brevicauda*)
Invertivorous Bird	American Woodcock (*Scolopax minor*)
Large Omnivorous Mammal	Red Fox (*Vulpes vulpes*)
Carnivorous Bird	Red-Tailed Hawk (*Buteo jamaicensis*)

The terrestrial food web model utilized soil EPCs based on COPEC soil concentrations measured in samples collected from the Ash Site as described in previous chapters of this report. The life history parameters for the surrogate species used to assess terrestrial feeding guilds at OU2 are presented in **Table 5.2-5**. The biological fate and transport parameters used to estimate the exposure point concentrations of COPECs are presented in **Table 5.2-6**. The exposure point concentrations for COPECs in the terrestrial food web are presented in **Table 5.2-7**. The COPEC doses for each feeding guild assessed in the terrestrial food web model are presented in **Tables**

N-1 through **Table N-8** in **Appendix N**. The avian and mammalian toxicity reference values used in the terrestrial food web model are presented in **Tables N-9** and **N-10** in **Appendix N**, respectively. The estimated ecological hazard quotients for each COPEC and each feeding guild assessed in the terrestrial food web model are presented in **Tables N-11** through **N-18** in **Appendix N**.

Table 5.2-12 presents a summary of the EHQ calculated for the terrestrial food web model assuming NOAEL-based TRVs. As presented in **Table 5.2-12**, several of the COPECs (i.e. arsenic, barium, mercury, selenium, and thallium) produce EHQs greater than one, indicating the potential for ecological hazard to one or more terrestrial feeding guilds (shaded HQ values). It is important to recognize that all of the EHQs calculated in this terrestrial food web model utilized TRVs which are based on NOAELs. A NOAEL is the highest concentration in a toxicity test at which no adverse effects are observed. As such, the EHQs are conservative and provide a significant level of protectiveness for the feeding guilds assessed.

Table 5.2-12

Summary of Terrestrial Food Web NOAEL-Based Ecological Hazard Quotients

Terrestrial Feeding Guild	NOAEL-Based Ecological HQs						
	As	Ba	me-Hg	Hg	Ni	Se	Tl
Herbivorous Bird	4.14E-03	3.35E-03	2.18E-04	1.16E-05	3.76E-05	4.86E-04	2.24E-04
Herbivorous Mammal	1.65E-01	3.05E+00	9.68E-04	7.55E-04	9.78E-04	6.20E-02	1.12E-01
Omnivorous Small Mammal	9.72E-01	1.84E+01	1.32E-01	2.77E-03	2.97E-03	6.80E-01	1.39E+00
Omnivorous Bird	4.05E+00	2.76E+00	2.96E+00	8.97E-03	2.76E-02	7.20E-01	3.68E-01
Invertivorous Small Mammal	1.43E+00	2.23E+01	2.64E-01	3.08E-03	2.90E-03	1.22E+00	2.61E+00
Invertivorous Bird	1.61E+00	1.01E+00	1.85E+00	2.99E-03	8.73E-03	3.44E-01	1.80E-01
Omnivorous Large Mammal	1.06E-02	1.54E-01	1.24E-03	3.33E-05	3.79E-05	7.42E-03	1.56E-02
Carnivorous Bird	4.11E-03	2.69E-03	5.32E-03	7.51E-06	2.03E-05	9.17E-04	4.82E-04

Table 5.2-13 presents a summary of the EHQs calculated for the terrestrial food web model assuming LOAEL-based TRVs. As presented in **Table 5.2-13**, arsenic and barium produce EHQs greater than one, indicating the potential for ecological hazards to the omnivorous bird feeding guild. All of the other EHQs are less than one for all of the other COPECs and feeding guilds. It is important to note that these food web models, by their conservative design and the current state of the science of ecological risk assessment, assess sensitive individuals within each feeding guild, and do not assess ecological populations or communities. USEPA (1997) guidance provides for the assessment of ecological communities and/or populations; however, the current state of the science of ecological risk assessment does not support population-level assessments. In order to account for the difference between adverse impacts to individuals and adverse impacts at the population level, the *de minimus* HQ of one could be raised to some

higher level; for instance 5 or 10. If the *de minimus* HQ were assumed to be 5 to account for population-level impacts, then all of the calculated HQs would be less than the *de minimus* level and no food web impacts to terrestrial populations would be expected.

Table 5.2-13

Summary of Terrestrial Food Web LOAEL-Based Ecological Hazard Quotients

Terrestrial Feeding Guild	LOAEL-Based Ecological HQs						
	As	Ba	me-Hg	Hg	Ni	Se	Tl
Herbivorous Bird	2.26E-03	1.67E-03	2.18E-05	1.16E-06	2.28E-05	2.43E-04	2.24E-05
Herbivorous Mammal	9.20E-02	4.95E-03	1.94E-04	7.55E-05	4.89E-04	4.45E-03	1.12E-02
Omnivorous Small Mammal	5.42E-01	2.99E-02	2.63E-02	2.77E-04	1.49E-03	4.87E-02	1.39E-01
Omnivorous Bird	2.21E+00	1.38E+00	2.96E-01	8.97E-04	1.68E-02	3.60E-01	3.68E-02
Invertivorous Small Mammal	7.96E-01	3.63E-02	5.27E-02	3.08E-04	1.45E-03	8.78E-02	2.61E-01
Invertivorous Bird	8.78E-01	5.04E-01	1.85E+01	2.99E-04	5.30E-03	1.72E-01	1.80E-02
Omnivorous Large Mammal	5.93E-03	2.50E-04	2.48E-04	3.33E-06	1.89E-05	5.32E-04	1.56E-03
Carnivorous Bird	2.24E-03	1.34E-03	5.32E-04	7.51E-07	1.23E-05	4.58E-04	4.82E-05

HQ – hazard quotient.
LOAEL – lowest observed adverse effect level.

5.2.6 SLERA Uncertainty Analysis

Uncertainties are inherent in any risk assessment, and even more so in a SLERA due to the nature of the assessment process and the assumptions used in the process. A number of the major areas of uncertainty in this assessment are discussed below and summarized in **Table 5.2-14** at the end of this section. In general, uncertainties in risk assessments are mitigated by making conservative assumptions so that risks are not under-estimated, resulting in a conservative risk assessment.

5.2.6.1 Uncertainties in Exposure Point Concentration Estimation

The uncertainties in the estimation of exposure point concentrations contribute a minor degree of uncertainty to the overall uncertainty in this SLERA. Constituent concentrations were measured in surface soil at the Ash Site and statistically analyzed to determine the most representative exposure point concentration for each constituent. Although significant uncertainties are inherent in all environmental sampling and analysis, the measured constituent concentrations contribute significantly less uncertainty to the SLERA than if fate and transport modeling were used to estimate constituent concentrations.

One source of uncertainty is associated with the sampling methodology used to collect surface soil samples at OU2. Due to the size of OU2 and the nature of the material present, composite sampling techniques were used to characterize surface soil at OU2. Composite samples provide a good estimation of the constituent concentrations an ecological receptor could be exposed to if they utilized OU2 in its entirety during the receptor's lifetime. However, composite sampling is limited in its ability to differentiate distinct areas of constituent concentrations, if they exist.

A certain level of uncertainty exists in the database for arsenic, chromium, and mercury specifically. Environmental samples were analyzed for total arsenic, total chromium, and total mercury, and the speciated forms of these constituents were not determined. The most common form of arsenic in environmental samples is the organic form, which is toxicologically inert. For this SLERA it was assumed that a percentage of the total arsenic was in the inorganic form; therefore, potentially over-estimating the toxicity of the detected arsenic in surface soil.

The most common forms of chromium in environmental samples are the trivalent form and the hexavalent form. These two species of chromium have very different toxicological properties. Because the sample analyses did not differentiate between chromium species, both the trivalent and hexavalent forms of chromium were assessed in this SLERA. For the food web models in this SLERA it was assumed that all of the chromium detected in environmental samples was in both the trivalent and hexavalent form; in essence, "double-counting" the detected chromium. This assumption introduces uncertainty into the ecological hazards estimated for chromium through food web interactions.

Mercury is also commonly found in both the elemental form and in the methylated form. Chemical analysis of environmental samples from the Ash Site included the analysis of total mercury only. Elemental and methyl-mercury have very different transport and toxicological properties. Per USEPA (1999) guidance, it was assumed that two percent of the total detected mercury in surface soil was in the methylated form and 98 percent was in the divalent form. This assumption introduces uncertainty into the ecological hazards estimated for mercury.

5.2.6.2 Uncertainties in COPEC Identification

The process for the identification of COPECs has a number of sources of uncertainty. The URS values used for identifying COPECs may not be applicable to site-specific conditions at OU2, thereby possibly including or excluding constituents erroneously from further evaluation.

Per DNREC directive, the COPEC identification process used background values from Dover AFB to characterize the background levels of inorganic constituents. It is unknown if the Dover AFB background data set accurately represents background conditions in the vicinity of the Ash Site.

5.2.6.3 Uncertainties in Media Concentration Estimation

Some of the greatest uncertainties in this SLERA are introduced in the estimation of COPEC concentrations in food items in the food web model. The use of simplified transfer rates and BAFs to estimate the transfer of COPECs from abiotic media to plant and animal tissues introduces uncertainty to the risk assessment. These transfer processes are often complicated physio-chemical processes that are regulated by biological systems, chemical properties of the COPECs, and many other site-specific environmental variables. It is practically impossible to model these processes accurately for all of the COPECs and all of the receptor species considered in this risk assessment. Therefore, for ease of calculation, simplified transfer rates (BAFs) are used to estimate to the best of our ability these complicated processes. In order to err on the side of protectiveness, the transfer rates used in this assessment are generally upper-bound estimates and tend to over-estimate the transfer of COPECs from abiotic media to plant and animal tissues.

5.2.6.4 Receptor Uncertainties

There are several uncertainties regarding potential receptor groups for which ecological risks cannot be estimated or are estimated within the context of different feeding guilds or ecological communities. It has been postulated (Sample and Suter, 2002) that ungulates (i.e. white-tail deer) may utilize coal ash as a source of sodium in order to supplement their normal sodium-deficient diets, much like their use of salt licks and road-side salt deposits. These potential exposures were not quantified at the Ash Site due to the fact that there are likely no resident deer populations on the island (no permanent fresh water source for drinking) and the isolated nature of the island ensures that a significant physical effort (e.g. it would be necessary to swim across either Island Creek or Indian River) would be required to access the island in order to access the coal ash. Therefore, this potential exposure pathway was deemed unlikely at the Ash Site.

Reptiles and amphibians were not directly assessed in this SLERA "because of the paucity of toxicological information on these receptors" (USEPA, 1999) and the lack of bio-uptake factors and models for amphibians and reptiles (Suter, et al., 2000). Aquatic forms of these receptor groups were assessed indirectly in the SLERA conducted for OU1 and OU3 presented in the FE (Shaw, 2008). The assessment of surface water and sediment communities in that SLERA incorporates aquatic forms of reptiles and amphibians.

Potential exposures of shorebirds to ash material were not assessed in the OU2 SLERA because they were assessed in the OU1 and OU3 SLERA presented in the FE report (Shaw, 2008). It was assumed for the OU1 and OU3 SLERA that invertivorous birds would consume invertebrates that had bioaccumulated constituents from the shoreline sediment. These receptors were determined to not be at risk from ash-related constituents.

5.2.6.5 Uncertainties in Food Web Model

Food web models have a significant degree of uncertainty associated with them simply because they are relatively simple mathematical relationships used to represent very complex biological relationships. Uncertainty is inherent in their simplified approach to a complex process. In the food web model, a single surrogate species is used to represent an entire feeding guild. Within the feeding guild are possibly hundreds of species, each with individual feeding behaviors and other subtle differences in behavior. The reason a single species is used as a surrogate for an entire feeding guild is that calculating exposures for each individual species in a given habitat is impossible due to the sheer numbers of species and complexities in different behaviors. Use of a single surrogate species for a given feeding guild is a reasonable approximation and this method is utilized for ease of calculation. It is likely that certain exposures are under-estimated and others are over-estimated using a single surrogate species. The effect on the results of the risk assessment is unknown.

Each exposure parameter in the food web model is represented by a single upper-bound point estimate for the given surrogate species. The use of a single point estimate for each exposure parameter is for ease of calculation. The upper-bound point estimates for each exposure parameter ensures that exposures are not under-estimated. The result of this simplification is that exposures are routinely over-estimated for most species in a given feeding guild.

Food web models utilize simplified feeding preferences for each feeding guild. It is normal practice to assume each feeding guild is exposed to two or three major food sources. In nature, these feeding guilds may feed on numerous food sources and their feeding preferences may change based on prey availability, season, age, and many other environmental factors. The food items selected for the food web models represent the major food preferences of the given feeding guild and also represent the greatest potential for exposure to COPECs for each feeding guild. As such, the simplification of the feeding behaviors for each feeding guild acts to maximize their potential exposures to COPECs and as such imparts a conservative bias on the estimation of exposure to COPECs.

The food web model in this assessment and most ecological risk assessments do not consider the inhalation and dermal exposure pathways. In general, inhalation and dermal exposures are considered negligible compared to the ingestion pathway for ecological receptors. Therefore, the exclusion of these potential exposure pathways is considered to impart a non-conservative bias on the results of the risk assessment, albeit at a relatively low level.

5.2.6.6 Uncertainties in Toxicity Assessment

As is common practice in most ecological risk assessments, literature-based toxicity values are used in this assessment based on their relative availability. Because site conditions are not considered in the derivation of these toxicity values, there is uncertainty in their applicability in the ecosystems and feeding guilds present at the Ash Site. Literature-based toxicity values may under- or over-estimate the toxicity of the COPECs identified at the site. The level of uncertainty introduced to this assessment by using literature-based values is unknown.

There also is no consideration given to the bioavailability of COPECs to different organisms. In this risk assessment it is assumed that all constituents are 100 percent bioavailable to all receptor organisms. It is known that many constituents (particularly inorganic compounds) have significantly lower bioavailabilities (i.e., 1 to 10 percent for some inorganics in soil) than the 100 percent that was assumed in this assessment. This assumption has the potential to greatly overestimate exposures to certain COPECs.

The toxicity values used in this assessment are all the most conservative values from the scientific literature and many are based on the most sensitive endpoint (NOAEL values) for the most sensitive species tested. A less sensitive endpoint that is still protective of the ecological populations or communities of interest may be the LOAEL or some other endpoint. The use of NOAEL-based toxicity values may overestimate potential for hazards from certain COPECs.

Another area of uncertainty is the lack of consideration of synergisms and/or antagonisms between COPECs. Although it is widely accepted that synergisms and antagonisms occur between certain constituents under certain conditions found in natural ecosystems, the science of ecological risk assessment as it is currently practiced does not provide methods for assessing these potential synergisms/antagonisms.

Perhaps the largest uncertainty is introduced to the toxicity assessment through the use of the most sensitive toxicity value for each COPEC for all mammals or birds. Per common ecological risk assessment practice, species-specific toxicity values are not derived in this assessment. Rather, it is assumed that all mammals exhibit the same susceptibility to adverse impact from a given COPEC; likewise all birds exhibit the same susceptibility to adverse impact from a given COPEC. Species-specific tolerances, metabolisms, body weights, behaviors, and other factors are not considered in this assessment. This simplification of the toxicological impacts of each COPEC is assumed due to the high level of uncertainty involved in deriving species-specific toxicity values from limited toxicological data. Although this simplification is justified due to the lack of toxicological data, this practice potentially introduces a significant degree of uncertainty to the toxicity assessment and subsequently, the risk assessment results.

5.2.6.7 Uncertainties in Risk Characterization

An area of potentially significant uncertainty in the risk characterization is the inherent limitations of the ecological hazard quotient method for estimating risks. EHQs are not explicit expressions of risk (i.e. they are not probabilities of toxicological effects occurring in an ecological population). Additionally, because EHQs are ratios, after unity has been exceeded, the magnitude of the EHQ has little bearing on the potential severity of adverse effects that may be anticipated. An EHQ of five does not indicate the potential ecological hazard is greater than an EHQ of three. Ecological hazard quotients are not population measures, but rather measures based on sensitive individuals from a test population. Therefore, an EHQ greater than one may indicate potential hazard to a sensitive sub-population of a given feeding guild, but the general population of that same feeding guild may not be at risk. For this reason, the EHQ method of assessing potential hazards imparts a conservative bias on the risk assessment results. As stated previously, uncertainties in risk assessments are mitigated by making conservative assumptions so that risks are not under-estimated, resulting in a conservative risk assessment that likely overestimates overall risks.

Table 5.2-14

Uncertainty Analysis Summary

	Key Assumptions	Rationale	Potential Effect on Risk	Magnitude of Effect
Exposure Point Concentrations	1) Use of 95%-UCL as EPC 2) Composite samples used to characterize surface soil at OU2 and to estimate soil exposures. 3) Speciation of arsenic, chromium, and mercury not accounted for.	1) Ensure EPCs are not under-estimated 2) Characterize maximum area of Burton Island with a reasonable number of samples. 3) Metals analyzed for total recoverable concentrations.	1) Over-estimate 2) Under-estimate 3) Unknown	1) Moderate 2) Moderate 3) Unknown
COPEC Identification	1) URS values do not account for site-specific conditions. 2) Background data set from Dover AFB.	1) Not practical in a SLERA 2) Representative of background conditions in DE.	1) Unknown 2) Unknown	1) Unknown 2) Unknown
Media Concentration Estimation	1) No consideration of COPEC bioavailability 2) All media within foraging range equally affected 3) Simplified transfer rates to estimate COPEC concentrations in food items	1) Ensure exposures are not underestimated 2) Ensure exposures are not underestimated 3) Ease of quantification	1) Over-estimate 2) Over-estimate 3) Over-estimate	1) High 2) High 3) High
Receptors	1) No quantification of exposure from ungulates using ash as sodium source 2) No quantification of risk to reptiles and amphibians	1) Unlikely to be a significant exposure route 2) No toxicity data	1) Under-estimate 2) Under-estimate	1) Low 2) Low
Food Web Model	1) Single surrogate species to represent entire feeding guild 2) Single upper-bound point estimate to represent each exposure parameter 3) Simplified feeding preferences to represent complex feeding behavior 4) No consideration of dermal or inhalation exposures	1) Different species within a given feeding guild are exposed through similar pathways 2) Ensures exposures are not underestimated 3)Ensures major exposure pathways are emphasized 4) Negligible exposures compared to ingestion	1) Unknown 2) Over-estimate 3) Over-estimate 4) Under-estimate	1) Unknown 2) High 3) Moderate 4) Low
Toxicity Assessment	1) Literature-based toxicity reference values may not represent on-site conditions 2) Toxicity of COPECs to the most sensitive mammal or bird tested is applicable to all mammals or birds at the site 3) Toxicity reference values based on NOAELs	1) Site-specific data are not available 2) Uncertainty of deriving toxicity values for each surrogate species is too great 3) Ensures protection of sensitive receptors	1) Over- and Under-estimate 2) Unknown 3) Over-estimate	1) Unknown 2) High 3) High
Risk Characterization	1) Measurement endpoints are protective of entire feeding guild 2) EHQ > 1 indicates potential risk to entire feeding guild	1) Assessment of sensitive individuals is protective of entire feeding guild 2) Assessment of sensitive receptors is protective of entire feeding guild	1) Over-estimate 2) Over-estimate	1) High 2) Unknown

Notes:
The “Potential Effect on Risk” are qualitative estimates of the effect the assumptions have on the risk assessment results.
The “Magnitude of the Effect” are qualitative estimates of the magnitude of the effect the assumptions have on the risk assessment results.
In general, uncertainties in risk assessments are mitigated by making conservative assumptions so that risks are not under-estimated, resulting in a conservative risk assessment.

5.2.7 SLERA Summary and Conclusions

A SLERA was conducted in order to assess the potential hazards from exposures to surface soil at OU2 (upland portion of Burton Island) of the Ash Site. The SLERA for OU1 (shoreline) and OU3 (off-shore) of the Ash Site is presented in the FE report (Shaw, 2008).

The SLERA for OU2 was conducted in accordance with the guidelines set forth in *Remediation Standards Guidance under the Delaware Hazardous Substance Cleanup Act* (DNREC, 1999) which stipulates that SLERAs be conducted according to *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA, 1997) and *Framework for Ecological Risk Assessment* (USEPA, 1992). This SLERA constitutes Steps 1 and 2 of the USEPA's eight-step ecological risk assessment process (USEPA, 1997).

5.2.7.1 Environmental Setting

Burton Island is a peninsula that extends into the Indian River Estuary, with the Indian River to the north and east, Island Creek to the south, and the Indian River Generating Station to the west. The western portion of Burton Island contains the Indian River Generating Station and associated buildings and paved areas, and the larger area to the east is the Ash Site. These relatively recently disturbed areas now support a variety of upland vegetation. Tree species observed during recent site work were primarily fast growing and early successional species including loblolly pine (*Pinus taeda*), black cherry (*Prunus serotina*), eastern red cedar (*Juniperus virginiana*), sweetgum (*Liquidambar styraciflua*), and devil's-walking-stick (*Aralia spinosa*).

As presented in Section 2.4, the dominant vegetative communities within OU2 and their percent coverage of the surface area of OU2 include the following:

- Common reed dominated upland 29.1%
- Bayberry/loblolly pine dominated upland 21 %
- Loblolly pine/common reed dominated upland 14.2 %
- Black locust dominated upland 13.9 %
- Bayberry/red maple dominated wetland transition 11.3 %

Other vegetative communities and habitat types each covered less than 5 percent of the total area of OU2.

Although wildlife species survey data are not available specifically for Burton Island, a species checklist for the nearby Assawoman Wildlife Area (AWA) shows that the following mammals may be present:

- White-tailed Deer
- Squirrel Southern Flying Squirrel
- Striped Skunk
- River Otter
- Eastern Mole
- White-footed Mouse
- Grey Squirrel
- Eastern Cottontail
- Red Fox
- Muskrat
- Masked Shrew
- Delmarva Fox
- Raccoon
- Gray Fox
- Meadow Vole
- Cotton Rat

The AWA data also include 162 species of birds, 12 species of reptiles and 12 species of amphibians (Gano, 1996). A detailed description of the habitats and dominant species found at OU2 is presented in Section 2.4.2 of this report.

Vegetation in the riparian and intertidal areas of Burton Island include the shrubs eastern baccharis (*Baccharis halimifolia*) and marsh elder (*Iva frutescens*), as well as the grasses smooth cordgrass (*Spartina alterniflora*), and common reed (*Phragmites australis*). Fiddler crab (*Uca pugnax*) colonies were observed among *Spartina* growth in the intertidal zone on the southeast portion of the Island. The riparian areas of Burton Island also provide habitat for wading birds including great egret (*Ardea alba*), snowy egret (*Egretta thula*), and great blue herron (*Ardea herodias*). These birds prey on the abundant small fish in the shallow waters surrounding the Island. Osprey (*Pandion haliaetus*) have historically had robust populations in the region, and several breeding pairs utilize nest platforms erected on Burton Island. These fish-eating raptors prey on menhaden that were observed to be abundant in the vicinity of Burton Island, as well as other fish species in the estuary and near-shore ocean waters.

The waters adjacent to Burton Island (Indian River and Island Creek) are tidal estuarine waters with a salinity range of about 10-22 ppt. The waters are part of a tidal system that includes Indian River Bay and Rehoboth Bay, and which discharges to the Atlantic Ocean through the Indian River Inlet. The waters near Burton Island are quite shallow as are the bays, which have an average depth of 3-8 feet. The estuary is poorly flushed by tidal exchange, meaning that it takes numerous tidal cycles to remove constituents from the system (DNREC, 2001). The ponds located near the eastern tip of the Ash Site are similar to the surrounding waters and are likely contiguous with the surrounding surface waters during certain tidal stages. The overall condition of the Delaware Inland Bays (not specific to the areas surrounding Burton Island) have been rated "fair" based on four indices utilized by the USEPA NCA. The indices evaluated the Delaware Inland Bay's water quality as fair, sediment quality and benthic invertebrate community quality as poor, and fish tissue quality was rated good (USEPA, 2006).

It should also be noted that the DNREC Division of Water Resources currently prohibits the harvesting of shellfish from the waters surrounding Burton Island and other areas of the Delaware Inland Bays due to the potential for bacterial pollution not related to the Ash Site or the Indian River Generating Plant. There are no fish consumption advisories related to metals in the Delaware Inland Bays.

The USFWS has indicated that, except for occasional transients, no proposed or federally listed species were known to exist within the project area. NMFS indicates that several species of sea turtles including loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempi*) and green sea turtle (*Chelonia mydas*) may be found in the Indian River near Burton Island, but that no effects to these species would occur from project activities.

The DNREC Natural Heritage and Endangered Species Program has not surveyed the site; however, they do have records of black vulture (*Coragyps atratus*) in the vicinity of the Ash Site, but according to DNREC "this species should not be impacted unless the forested portion of the parcel is going to be disturbed." In addition, there are two bald eagle nests upstream and trees along the shore are likely utilized for roosting and foraging (DNREC, 2007).

5.2.7.2 Problem Formulation

In order to identify the various ecosystems and communities potentially impacted by ash material from the Ash Site and the pathways by which those receptors could potentially be exposed, an ecological conceptual site model (Eco-CSM) was developed. The Eco-CSM for OU2 is presented in **Figure 5.2-2**. Using the Eco-CSM as a guide, assessment and measurement endpoints were identified. Assessment endpoints were selected for each mammal and bird feeding guild and each soil community. Assessment endpoints for guilds or communities reflect protection of one or more attributes of those receptors. In general, the assessment endpoints for this SLERA included the following:

- Soil invertebrate survival, growth, and productivity;
- Terrestrial plant survival, growth, and productivity;
- Herbivore survival, growth, and productivity;
- Omnivore survival, growth, productivity;

- Invertivore survival, growth, productivity; and
- Carnivore survival, growth, productivity.

Table 5.2-2 presents summaries of the valued ecological entities, representative receptor species, and the ecological attributes/functional roles for the terrestrial habitats at OU2.

5.2.7.3 Risk Characterization

Measures of effects were divided into two general categories for this SLERA: community-level measures of effect and food web measures of effect. Ecological hazards for community-level receptors were estimated by calculating EHQs for each COPEC in surface soil from the Ash Site. Community-level EHQs were estimated via the following relationship:

$$EHQ_{comm} = \frac{EPC}{TRV_{comm}}$$

where:

EHQ_{comm}	=	community-level ecological hazard quotient (unitless);
EPC	=	exposure point concentration (mg/kg); and
TRV_{comm}	=	community-level toxicity reference value (mg/kg).

Ecological hazards for higher trophic level organisms that could potentially be exposed to surface soil from the Ash Site through food web interactions were estimated by calculating EHQs for each COPEC in terrestrial ecosystems. These indirect exposure EHQs were estimated via the following relationship:

$$EHQ_{web} = \frac{TDD}{TRV_{web}}$$

where:

EHQweb	=	ecological hazard quotient for food web receptors (unitless);
TDD	=	total daily dose of COPEC ingested by surrogate species (mg/kg-day); and
TRVweb	=	toxicity reference value for mammalian or avian receptor species (mg/kg-day).

<u>Soil Community Assessment</u>.

Soil communities assessed in this ecological risk assessment include terrestrial plants and terrestrial invertebrates. As such, the soil communities that were assessed herein encompass

OU2. Plant communities and terrestrial invertebrate communities were assessed by comparing estimated soil exposure point concentrations to TRVs for the protection of terrestrial plants and terrestrial invertebrates. The EHQ values for the COPECs identified in surface soil at OU2 are shown in **Table 5.2-4** copied here for ease of reference.

Table 5.2-4

Community-Level Ecological Hazard Assessment

Surface Soil COPEC	**EPC** (mg/kg)	**Terrestrial Plant ESV** (mg/kg)	**Terrestrial Plant HQ**	**Terrestrial Invertebrate ESV** (mg/kg)	**Terrestrial Invertebrate HQ**
Arsenic	150	18 [a]	8.33	60 [c]	2.5
Barium	526	500 [b]	1.05	330 [a]	1.59
Mercury	0.558	0.3 [b]	1.86	0.1 [c]	5.58
Nickel	37.1	38 [a]	0.98	280 [a]	0.13
Selenium	4.3	0.52 [a]	8.27	4.1 [a]	1.05
Thallium	1.58	1 [b]	1.58	NA	NC

Notes:
COPEC – constituent of potential ecological concern.
EPC – exposure point concentration.
ESV – ecological screening value.
HQ – hazard quotient.
mg/kg – milligram per kilogram.
NA – Not Available
NC – Not Calculated
[a] USEPA Eco-SSLs
[b] Efroymson, et al. (1997a). Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.
[c] Efroymson, et al. (1997b). Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision.

The soil EPCs for arsenic, barium, mercury, selenium, and thallium exceed their respective terrestrial plant and terrestrial invertebrate screening values and indicate the potential for ecological hazards to these soil communities.

Terrestrial Food Web Assessment.

Terrestrial habitats at the Ash Site were assessed in this SLERA via a terrestrial food web model. The terrestrial food web model utilized surrogate receptor species to represent the different feeding guilds that utilize the upland portion of the Ash Site for feeding, nesting, and other normal activities. The feeding guilds and their representative surrogate species assessed in the terrestrial food web model are listed in **Table 5.2-3** copied here for ease of reference.

Table 5.2-3

Representative Surrogate Species for Feeding Guilds Within OU2

Feeding Guild	Surrogate Species
Herbivorous Bird	Canada Goose (*Branta canadensis*)
Herbivorous Mammal	Eastern Cottontail (*Sylvilagus floridanus*)
Small Omnivorous Mammal	White-Footed Mouse (*Peromyscus leucopus*)
Omnivorous Bird	American Robin (*Turdus migratorius*)
Invertivorous Mammal	Short-Tailed Shrew (*Blarina brevicauda*)
Invertivorous Bird	American Woodcock (*Scolopax minor*)
Large Omnivorous Mammal	Red Fox (*Vulpes vulpes*)
Carnivorous Bird	Red-Tailed Hawk (*Buteo jamaicensis*)

The terrestrial food web model assessed the upland portion of the Ash Site. The input parameters, exposure point concentrations, estimated daily exposure rates, and estimated hazards for the terrestrial food web model are presented in **Tables N-1** through **N-18** in **Appendix N.** The terrestrial food web model utilized measured surface soil concentrations and modeled food concentrations of COPECs to estimate total potential exposures for terrestrial feeding guilds. The results of the terrestrial food web model are summarized in **Table 5.2-12** (copied here for ease of reference) assuming NOAEL-based TRVs. As presented in **Table 5.2-12**, several of the COPECs (i.e. arsenic, barium, mercury, selenium, and thallium) produce EHQs greater than one, indicating the potential for ecological hazard to one or more terrestrial feeding guilds (shaded HQ values).

Table 5.2-12

Summary of Terrestrial Food Web NOAEL-Based Ecological Hazard Quotients

Terrestrial Feeding Guild	NOAEL-Based Ecological HQs						
	As	Ba	me-Hg	Hg	Ni	Se	Tl
Herbivorous Bird	4.14E-03	3.35E-03	2.18E-04	1.16E-05	3.76E-05	4.86E-04	2.24E-04
Herbivorous Mammal	1.65E-01	3.05E+00	9.68E-04	7.55E-04	9.78E-04	6.20E-02	1.12E-01
Omnivorous Small Mammal	9.72E-01	1.84E+01	1.32E-01	2.77E-03	2.97E-03	6.80E-01	1.39E+00
Omnivorous Bird	4.05E+00	2.76E+00	2.96E+00	8.97E-03	2.76E-02	7.20E-01	3.68E-01
Invertivorous Small Mammal	1.43E+00	2.23E+01	2.64E-01	3.08E-03	2.90E-03	1.22E+00	2.61E+00
Invertivorous Bird	1.61E+00	1.01E+00	1.85E+00	2.99E-03	8.73E-03	3.44E-01	1.80E-01
Omnivorous Large Mammal	1.06E-02	1.54E-01	1.24E-03	3.33E-05	3.79E-05	7.42E-03	1.56E-02
Carnivorous Bird	4.11E-03	2.69E-03	5.32E-03	7.51E-06	2.03E-05	9.17E-04	4.82E-04

Table 5.2-13 (copied here for ease of reference) presents a summary of the EHQs calculated for the terrestrial food web model assuming LOAEL-based TRVs. As presented in **Table 5.2-13**, arsenic and barium produce EHQs greater than one, indicating the potential for ecological

hazards to the omnivorous bird feeding guild. All of the other EHQs are less than one for all of the other COPECs and feeding guilds.

Table 5.2-13

Summary of Terrestrial Food Web LOAEL-Based Ecological Hazard Quotients

Terrestrial Feeding Guild	LOAEL-Based Ecological HQs						
	As	Ba	me-Hg	Hg	Ni	Se	Tl
Herbivorous Bird	2.26E-03	1.67E-03	2.18E-05	1.16E-06	2.28E-05	2.43E-04	2.24E-05
Herbivorous Mammal	9.20E-02	4.95E-03	1.94E-04	7.55E-05	4.89E-04	4.45E-03	1.12E-02
Omnivorous Small Mammal	5.42E-01	2.99E-02	2.63E-02	2.77E-04	1.49E-03	4.87E-02	1.39E-01
Omnivorous Bird	2.21E+00	1.38E+00	2.96E-01	8.97E-04	1.68E-02	3.60E-01	3.68E-02
Invertivorous Small Mammal	7.96E-01	3.63E-02	5.27E-02	3.08E-04	1.45E-03	8.78E-02	2.61E-01
Invertivorous Bird	8.78E-01	5.04E-01	1.85E+01	2.99E-04	5.30E-03	1.72E-01	1.80E-02
Omnivorous Large Mammal	5.93E-03	2.50E-04	2.48E-04	3.33E-06	1.89E-05	5.32E-04	1.56E-03
Carnivorous Bird	2.24E-03	1.34E-03	5.32E-04	7.51E-07	1.23E-05	4.58E-04	4.82E-05

5.2.7.4 Conclusions

Ecological hazards were estimated for both community-level ecological receptors and higher trophic level receptors at OU2. Conservative assessment techniques were utilized for exposures and assessment endpoints. Surface soil samples collected from OU2 exhibit concentrations of several metals (arsenic, barium, mercury, selenium, and thallium) that may have the potential to adversely affect plants and soil invertebrates.

The results of the terrestrial food web model showed that the calculated EHQs for several of the feeding guilds were greater than one, indicating the potential, for ecological hazard due to exposures to COPECs in surface soil at OU2.

It is important to note that these food web models, by their conservative design and the current state of the science of ecological risk assessment, assess sensitive individuals within each feeding guild, and do not assess ecological populations or communities. USEPA (1997) guidance provides for the assessment of ecological communities and/or populations; however, the current state of the science of ecological risk assessment does not support population-level assessments. In order to account for the difference between adverse impacts to individuals and adverse impacts at the population level, the *de minimus* HQ of one could be raised to some higher level based on professional judgment and experience; for instance 5 or 10. If the *de minimus* HQ were assumed to be 5 to account for population-level impacts and LOAEL-based TRVs are assumed, then all of the calculated HQs would be less than the *de minimus* level and no food web impacts to terrestrial populations would be expected.

6.0 Summary and Conclusions

6.1 Summary

The following is a summary of the results of the Remedial Investigation (RI), which specifically addresses the data gaps identified in the risk assessment presented in the original Facility Evaluation (FE) and provides information to make informed decisions regarding OU2 under the Voluntary Cleanup Program (VCP).

6.1.1 Nature and Extent of Constituents

The RI field activities at Operable Unit No. 2 (OU2) included the collection of soil samples, pond sediment and surface water samples, and groundwater samples. New groundwater monitoring wells were installed and a tidal study was performed. Other activities including a survey of vegetative and habitat communities at OU2 and air dispersion modeling were performed in support of the revised risk assessments presented in this report.

Soil samples were collected from surface and subsurface depth intervals at 84 locations across the 93.6 acres of OU2 and composited into 14 samples for each depth interval.

One sediment and one surface water sample were collected from each of three ponds located at the eastern end of OU2. Constituent concentrations in sediment were similar between the FE and RI data sets for detected constituents except for aluminum, selenium and vanadium. Constituent concentrations in surface water were similar between the FE and RI data sets for detected constituents such that the findings of the FE are also applicable to the ponds.

Groundwater samples were collected from 14 monitoring wells, including 5 newly installed wells. The preliminary constituents of interest, based on a comparison to URS and background (MW-9) values, are arsenic, barium, iron and manganese. These constituents were considered for an analysis of mass loading to surface water. The tidal study results were used to refine the CSM and to determine that Burton Island groundwater does not communicate with potable water aquifers on the opposite shorelines.

6.1.2 Fate and Transport

The major potential transport mechanism for OU2-related constituents to enter the environment is through leaching from the ash material into local groundwater and the transport of this leachate with local groundwater flow. The groundwater flow regime beneath Burton Island is a dynamic system that reverses flow direction depending on the tidal fluctuations of Indian River and Island Creek. Although the direction of flow of impacted groundwater beneath Burton Island fluctuates depending on the tidal cycle, there is no pathway to potable water aquifers.

Groundwater at Burton Island does not connect to the local drinking water aquifer. In addition, the mass loading estimates indicated by this investigation are not expected to have a significant impact on surface water quality as documented by the sediment and surface water sampling results from the FE.

Other potential physical transport mechanisms for constituents in impacted media include soil transport via overland flow, and transport and dispersion via fugitive dust. The overland flow pathway is significantly minimized by the implementation of shoreline stabilization measures and not considered significant for the revised risk assessment. Although fugitive dust generation and transport via air dispersion is a potential transport mechanism for constituents in surface soil at Burton Island, this transport mechanism is considered insignificant. The results of the fugitive dust generation and dispersion analysis show that concentrations of particulate matter with aerodynamic diameter less than a nominal 10 micrometers (PM10) and particulate matter with aerodynamic diameter less than a nominal 2.5 micrometers (PM2.5) are expected to be less than their respective National Ambient Air Quality Standards (NAAQS) at the closest sensitive receptor locations assuming Burton Island remains vegetated at its current level. Based on this fugitive dust generation and dispersion analysis, the inhalation exposure pathway is considered to be negligible.

Other potential transport mechanisms, such as uptake by terrestrial plants, bioaccumulation into terrestrial organisms, and trophic transfer via the food web are addressed in the human health and screening level ecological risk assessments.

6.1.3 Risk Assessment

The human health and screening level ecological risk assessments presented in the original FE for OU2 were revised as part of this RI.

6.1.3.1 Human Health Risk Assessment

A human health risk assessment was conducted to determine the types and magnitudes of exposures to constituents originating from OU2 and to determine the potential carcinogenic risks and non-carcinogenic health hazards posed by the estimated exposures.

For this assessment, COPCs were identified in surface soil as those constituents whose EPC exceeded the URS for the protection of human health, based on restricted use in a critical water resource area and/or its associated background screening value (BSV). The only constituent that was identified as a COPC in surface soil at OU2 was arsenic. COPCs were identified in shoreline and offshore sediment as those constituents that were identified as "Important Bioaccumulative Compounds" by USEPA (2000) and whose maximum detected concentration exceeds local background concentrations. The COPCs that were identified in shoreline and offshore sediment samples are arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc.

The human health risk assessment evaluated the recreational fisherman receptor population for potential exposures to COPCs via ingestion of fish/shellfish and incidental ingestion of soil and dermal absorption of soil while trespassing on Burton Island.

The carcinogenic risks were calculated for arsenic, the only COPC considered carcinogenic. The estimated carcinogenic risks are within the USEPA's recommended risk range and marginally exceed DNREC's suggested limit. The risks from fish/shellfish ingestion are associated with OU1, and the risks from ingestion of soil and dermal absorption of soil are associated with OU2. If illegal trespassing on Burton Island was limited to fewer than 16 events per year, then all of the calculated risks associated with exposure to surface material at OU2 would be less than the recommended risk levels specified by USEPA and DNREC. Because land access is secure, because of the dense vegetation along the shoreline and the fact that the recent revetment projects add a factor of difficulty for boat access to 95 percent of OU1 (the shoreline surrounding OU2), illegal trespassing is highly unlikely. The fact that illegal trespassing on Burton Island has rarely been observed leads to the expectation that such a significant level of illegal trespassing (16 or more events per year by the same individual) would not occur.

The estimated non-carcinogenic hazard quotients are less than the USEPA's and DNREC's recommended target hazard index of 1.0, except for arsenic, which slightly exceeds the target hazard index of 1.0 for children. The hazards from fish/shellfish ingestion are associated with OU1, and the hazards from ingestion of soil and dermal absorption of soil are associated with OU2. If illegal trespassing is limited to fewer than 16 events per year as indicated in the previous paragraph, then all of the calculated hazards associated with exposure to surface material at OU2 would be less than the recommended hazard levels specified by USEPA and DNREC.

Although fish/shellfish ingestion was assessed in conjunction with OU1 and OU3 and it was determined that the "level of contamination present at Burton Island did not pose an undue health risk to an adult or child who may be exposed to the contaminants from eating fish from the local waters" (DNREC, 2008), this potential exposure pathway was incorporated into the assessment of OU2 in order to estimate total cumulative risks/hazards experienced by the recreational fisherman receptor population.

It should be noted that the DNREC Division of Water Resources currently prohibits the harvesting of shellfish from the waters surrounding Burton Island and other areas of the Delaware Inland Bays due to the potential for bacterial pollution not related to the Ash Site or the Indian River Generating Station. This shellfish harvesting prohibition effectively eliminates legal human exposures to shellfish from these prohibited areas (including the area surrounding Burton Island). There are no fish consumption advisories related to metals in the Delaware Inland Bays.

It is also interesting to note that in a recent study conducted to measure arsenic concentrations in marine fish in the Delaware Inland Bays, Greene and Crecelius (2006) found that fish migrating into the Inland Bays in the spring had higher concentrations of arsenic in their tissues than fish migrating out of the Inland Bays in the fall after spending the summer within the Inland Bays. These results indicate that the Inland Bays do not contribute significantly to the overall fish tissue burden of arsenic exhibited by migrating fish species.

Therefore, it can be concluded that site-related constituents in surface soil and sediment do not pose significant risks/hazards to the recreational fisherman receptor population except for arsenic, which has the potential for marginally increased carcinogenic risk and non-carcinogenic hazard assuming conservative exposure parameters. If more realistic exposure parameters are considered, all of the estimated carcinogenic risks and non-carcinogenic hazards associated with exposure to surface material at OU2 are less than the recommended risk/hazard levels specified by USEPA and DNREC.

6.1.3.2 Screening Level Ecological Risk Assessment

A SLERA was conducted in order to assess the potential hazards from exposures to surface soil at OU2. Measures of effects were divided into two general categories for this SLERA: community-level measures of effect and food web measures of effect. Ecological hazards for community-level receptors were estimated by calculating Ecological Hazard Quotients (EHQs) for each COPEC in surface soil including arsenic, barium, mercury, nickel, selenium, and thallium. Ecological hazards for higher trophic level organisms that could potentially be exposed to surface soil from the Ash Site through food web interactions were estimated by calculating EHQs for each COPEC in terrestrial ecosystems.

Soil Community Assessment

Soil communities assessed in this ecological risk assessment include terrestrial plants and terrestrial invertebrates. As such, the soil communities that were assessed herein encompass OU2. Plant communities and terrestrial invertebrate communities were assessed by comparing estimated soil exposure point concentrations to toxicity reference values (TRVs) for the protection of terrestrial plants and terrestrial invertebrates.

The soil EPCs for arsenic, barium, mercury, selenium, and thallium exceed their respective terrestrial plant and terrestrial invertebrate screening values and indicate the potential for ecological hazards to these soil communities. It should be noted that the plant and terrestrial invertebrate TRVs used in this assessment are based on laboratory studies using the most sensitive plant and invertebrate species available. As such, the TRVs may not represent the environmental conditions present at Burton Island, and may over-estimate the potential for ecological hazards to terrestrial plant and invertebrate communities.

Terrestrial Food Web Assessment

Terrestrial habitats at OU2 were assessed in this SLERA via a terrestrial food web model. The terrestrial food web model utilized surrogate receptor species to represent the different feeding guilds that utilize the upland portion of OU2 for feeding, nesting, and other normal activities.

The terrestrial food web model assessed OU2 utilizing measured surface soil concentrations and modeled food concentrations of COPECs to estimate total potential exposures for terrestrial feeding guilds. Several of the COPECs (i.e. arsenic, barium, mercury, selenium, and thallium) produce EHQs greater than one, indicating the potential for ecological hazard to one or more terrestrial feeding guilds. Based on the conservative LOAELs, the lowest observable adverse effect level, only arsenic and barium produce EHQs greater than one for the omnivorous bird feeding guild. Based on the NOAELs, the highest concentrations at which no affect is observed (and a more conservative comparison than LOAELs), the EHQs were greater than one for the herbivorous mammal (barium only), omnivorous small mammal (barium and thallium only), omnivorous bird (arsenic, barium, and methyl-mercury), invertivorous small mammal (arsenic, barium, selenium, and thallium), and invertivorous bird (arsenic, barium, and methyl-mercury) feeding guilds. EHQs were less than 1 for the herbivorous bird, omnivorous large mammal, and carnivorous bird feeding guilds.

Although the terrestrial food web model showed that the calculated EHQs for several of the feeding guilds were greater than one, it is important to note that these food web models, by their conservative design and the current state of the science of ecological risk assessment, assess sensitive individuals within each feeding guild, and do not assess ecological populations or communities. USEPA (1997) guidance provides for the assessment of ecological communities and/or populations; however, the current state of the science of ecological risk assessment does not support population-level assessments. In order to account for the difference between adverse impacts to individuals and adverse impacts at the population level, the *de minimus* EHQ of 1 could be raised to some higher level, for instance 5 or 10, based on experience and best professional judgment. If the *de minimus* EHQs were assumed to be 5 to account for population-level impacts, and lowest-observed-adverse-effect-level (LOAEL)-based TRVs are assumed, then all of the calculated EHQs would be less than the *de minimus* level and no food web impacts to terrestrial populations would be expected.

6.2 Conclusions

This RI was undertaken to address data gaps identified in the FE. The following conclusions were reached in the body of the report and are summarized below:

1. It has been determined that there is no groundwater pathway from OU2 to off-site receptors. Groundwater at Burton Island does not connect to the local drinking water aquifer. Therefore, no risk assessment revisions were performed to evaluate this pathway. This conclusion is supported in Section 3.3.5 Revised Conceptual Site Model, last paragraph on page 3-40; depicted on Figure 3.3-12; and summarized in Section 3.3.7 Findings, Finding #16, page 3-49.

2. Air dispersion modeling for wind-generated fugitive dust indicates particulate concentrations below published standards. No further risk assessment is required to evaluate this pathway. This conclusion is based on the analyses and determinations made throughout Section 4.0 Air Dispersion Modeling, and summarized in Section 4.4 Findings, first paragraph, page 4-6.

3. The investigation of the three ponds confirmed that the condition of the surface water and sediment in these ponds is consistent with the condition of the surface water and sediment in the adjacent Indian River and Island Creek. Thus, the following conclusions of the FE with regard to surface water and sediment are applicable to the three ponds investigated as part of this RI.

   For sediment:

   - no ecological hazard from exposure to sediment through food web interactions;

- possible but not probable potential for adverse effects on benthic invertebrates due to arsenic and barium in sediment; and

- no further ecological evaluation is recommended for sediment.

This conclusion is supported in Section 3.2.3.1 Pond Sediment COIs, pages 3-9 to 3-11, and summarized in Section 6.1.1 Nature and Extent of Constituents, page 6-1, third paragraph.

For surface water:

- no ecological hazard from exposure to surface water through food web interactions;

- the likelihood of adverse effects from exposure to arsenic and barium in surface water is minimal; and

- no further ecological evaluation is recommended for surface water.

This conclusion is supported in Section 3.2.3.2 Pond Surface Water COIs, pages 3-11 to 3-12, and summarized in Section 6.1.1 Nature and Extent of Constituents, page 6-1, third paragraph.

4. The Human Health Risk Assessment (HHRA) was revised to include analytical data from surface soil samples and to evaluate potential exposure to ash material by the trespassing recreational fisherman receptor via incidental ingestion and dermal contact. Based on the results of the FE and this RI, the human health risks associated with the most likely exposures to OU2 are only possible via illegal entry and trespassing and are limited to one receptor group and one constituent using standard conservative assumptions. That risk is within guidance levels using a realistic exposure scenario and current conditions. In addition, that risk would be managed with existing and enforced land use controls (i.e., controlling access to OU2). This conclusion is based on the analyses and determinations made throughout Section 5.1 Human Health Risk Assessment and summarized in Section 5.1.7 Human Health Risk Assessment Summary and Conclusions and Section 6.1.3.1, pages 6-2 to 6-4.

5. The Screening Level Ecological Risk Assessment (SLERA) was revised to include analytical data from surface soil samples and to incorporate site-specific Area Use Factors (AUFs) and habitat information. The conservative assessment techniques used in the SLERA indicated that several metals in surface soil at OU2 may have the potential to affect the site ecosystem. However, if food web models were utilized to assess ecological communities and populations instead of individuals, then all of the calculated hazards

would be less than the *de minimus* hazard levels and no food web impacts to terrestrial populations would be expected. Therefore, no further action would be warranted for the protection of terrestrial food web-based ecological communities and/or populations. This conclusion is based on the analyses and determinations made throughout Section 5.2 Screening Level Ecological Risk Assessment and summarized in Section 5.2.7 SLERA Summary and Conclusions and in Section 6.1.3.2 Screening Level Ecological Risk Assessment, pages 6-4 to 6-6.

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