The following are attachments to the prefiled answers of Mark Hutson.

ATTACHMENT 1

Dominion Resources Services, Inc.
5000 Dominion Boulevard, Glen Allen, VA 23060
Web Address: www.dom.com

Dominion

RECEIVED – DEQ
JUN 22 2010
Tidewater Regional
Office

June 18, 2010

Ms. Debra Trent
Department of Environmental Quality
Tidewater Regional Office
5636 Southern Boulevard
Virginia Beach, VA 23462

RE: ***Chesapeake Energy Center***
Landfill Permit No. 440
Corrective Action Plan
Interim Measures Report

Dear Ms. Trent:

Please find attached a copy of the interim measures report "Natural Attenuation of Arsenic Demonstration, Chesapeake Energy Center Ash Landfill, Chesapeake, Virginia". The objective of the interim measures action was to determine if arsenic concentrations in groundwater are reduced by natural processes. The report summarizes the data collected and the conclusion that arsenic is being removed from groundwater by reaction with iron oxides. This finding supports the monitored natural attenuation approach described in the corrective action plan.

We would like the opportunity to discuss the report with you at your earliest convenience. Mr. Donald Hintz of our office will be contacting you to arrange for a meeting. Should you have any questions or comments in the mean time, please feel free to contact me at (804) 273-2929 or Donald Hintz of Dominion Electric Environmental Services at (804) 273-3552.

Sincerely,

Cathy C Taylor

Cathy C. Taylor
Director
Electric Environmental Services

m
MARIA
DEBRA
KEITH

Dominion Resources Services, Inc.
5000 Dominion Boulevard, Glen Allen, VA 23060
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JAN 19 2010
Tidewater Regional Office

January 14, 2010

Ms. Debra Trent
Department of Environmental Quality
Tidewater Regional Office
5636 Southern Boulevard
Virginia Beach, VA 23462

RE: Chesapeake Energy Center, Landfill Permit No. 440
Corrective Action Plan, Interim Measures Notification

Dear Ms. Trent:

This notice is being provided pursuant to Virginia Regulation 9VAC 20-80-310.C.1.c, to conduct interim measures at the Chesapeake Energy Center (CEC) industrial landfill. The objective of this interim measures action is to identify natural attenuation zones in the estuary sediments in support of the monitored natural attenuation (adsorption) alternative, which is consistent with the goals of the Corrective Action Plan.

A description of the interim measures activities are included in the Supplemental Assessment Workplan contained within the Corrective Action Plan submitted to DEQ, dated February 2008, and in the draft Corrective Action Permit Module XIV, Section XIV.R.2. The proposed interim measures include:

1. A bathymetric survey of the estuary bottom near the shoreline of the landfill prior to collecting sediment cores.
2. Collection of shallow sediment cores (0-12 feet below the bottom of the Southern Branch Elizabeth River) using vibracore and plastic core barrels along transects perpendicular to the shoreline.
3. Analysis of sediment cores to accomplish two main objectives: determine the range of arsenic and iron concentration in the pore water and sediments above, within and below the redox boundaries, within individual cores and across the population of cores collected.
4. Analyze a total of four surface water samples collected near the coring stations to demonstrate the attenuation of arsenic.

The results of the interim measures will be incorporated into the evaluation of the final remedy for the site. The data collection phase for the interim measures is proposed to begin in February 2010 and be completed by March 2010. An investigation report will be prepared for submission to DEQ during the second quarter of 2010.

Should you have any questions or comments regarding the enclosed information, please contact Donald Hintz of Dominion Electric Environmental Services at (804) 273-3552.

Sincerely,

Cathy C Taylor

Cathy C. Taylor
Director, Environmental Services

cc: Milt Johnston
mljohnston@deq.virginia.gov

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Tidewater Regional
Office

Natural Attenuation of Arsenic Demonstration Chesapeake Energy Center Ash Landfill Chesapeake, Virginia

Submitted to:

Dominion Generation
Innsbrook Technical Center
5000 Dominion Boulevard
Glen Allen, VA 23060

Submitted by:

AMEC Earth & Environmental, Inc.
Albuquerque, NM

June 7, 2010

Project number: 1051700002

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Tidewater Regional Office

Natural Attenuation of Arsenic Demonstration
Dominion Generation
Chesapeake Energy Center Ash Landfill
Chesapeake, Virginia
Solid Waste Permit No. 440

June 7, 2010

Prepared for:	Dominion Generation Innsbrook Technical Center 5000 Dominion Boulevard Glen Allen, VA 23060
Contact:	Mr. Don Hintz (804) 273-3552

AMEC Earth & Environmental, Inc.

Peter A. Guerra Project Manager	Gregory P. Miller, Ph.D. Program Manager

EXECUTIVE SUMMARY

This report describes a study to determine if arsenic concentrations in groundwater are reduced by natural processes at an ash landfill located at the Chesapeake Energy Center (CEC). The study determined that arsenic is being removed from groundwater by reaction with iron oxides.

The current CEC ash landfill was constructed in 1985 on fill partly composed of ash from power plant operations. Saturated conditions in the fill have resulted in arsenic concentrations in groundwater under the landfill that are above the Virginia Department of Environmental Quality (VDEQ) Groundwater Protection Standard (GPS) of 10 µg/L. A proposal has been made for the site to be monitored while natural attenuation processes work to reduce arsenic concentrations at the landfill (Monitored Natural Attenuation – MNA).

Previous data collected have documented that:

- The concentration of arsenic in groundwater at the source is decreasing with time.
- The concentration of arsenic in off-site groundwater is being reduced by natural reactions in the aquifer.
- The rate and mechanism for natural attenuation of arsenic in groundwater support a Monitored Natural Attenuation approach to remediate arsenic to below the VDEQ GPS.

A field study was conducted to collect samples of Norfolk Formation aquifer materials, pore waters, surface water and groundwater samples. The study was proposed in the Supplemental Assessment Work Plan contained in the 2008 Corrective Action Plan and summarized in a January 2010 Interim Measures notification to VDEQ. The purpose of the study was to determine if the natural attenuation mechanisms previously reported were operable at the landfill. The study focused on the geochemistry of arsenic and iron in the Norfolk Formation.

This study confirmed and expanded on previous results. Dissolved iron in groundwater was found to be oxidizing in the subsurface below the waters of the South Branch of the Elizabeth River, Deep Creek, and the cooling water discharge channel. This oxidation results in the sand grains of the aquifers being coated in iron oxides and oxyhydroxides (rust). Arsenic has a very strong affinity for rust. The preferential binding of dissolved arsenic to rust—natural attenuation—was observed in all off-shore samples obtained from the Norfolk Formation.

Natural attenuation of arsenic has been observed on-shore and off-shore at the CEC ash landfill. Decline in groundwater arsenic concentrations are an ongoing and continuous process as determined from statistical analysis of compliance monitoring data. The concentration of arsenic in groundwater decreases with distance from the landfill. Decreases in groundwater arsenic to very near the GPS were observed in pore water (groundwater derived from sediment samples), and those decreases are correlated with distance (length of the reactive flow path) from the landfill. Natural attenuation is decreasing groundwater arsenic concentration through a known mechanism. Monitored Natural Attenuation is a viable remedial alternative for the CEC ash landfill.

ABBREVIATIONS

ACM	Assessment of Corrective Measures
AWQC	Ambient Water Quality Criteria
CAP	Corrective Action Plan
CAMP	Corrective Action Monitoring Plan
CEC	Chesapeake Energy Center
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPS	Groundwater Protection Standard
GSPS	Global Satellite Positioning System
HDPE	High Density Polyethylene
ICP-MS	Inductively Coupled Plasma-Mass Spectroscopy
ICP-OES	Inductively Coupled Plasma-Optical Emission
SBER	Southern Branch of the Elizabeth River
SAWP	Supplemental Assessment Work Plan
mg/L	Milligrams per Liter
mg/kg	Milligrams per Kilogram
ml/min	Milliliters per Minute
MSL	Mean Sea Level
MNA	Monitored Natural Attenuation
NCDC	National Climate Data Center
NES	Nature and Extent Study
NMBGMR	New Mexico Bureau of Geology and Mineral Resources
NOAA	National Oceanic and Atmospheric Administration
ORP	Oxidation-Reduction Potential
TOC	Top-of-Casing
µg/L	Micrograms per Liter
µg/kg	Micrograms per Kilogram
VDEQ	Virginia Department of Environmental Quality

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1.0 INTRODUCTION

A Corrective Action Plan (CAP) was prepared for the Chesapeake Energy Center (CEC) Ash Landfill (Solid Waste Permit No. 440) located in Chesapeake, Virginia. A site location map is included as **Figure 1-1**. The plan was required because dissolved arsenic had been detected at concentrations ranging from below the groundwater protection standard (GPS) of 10 µg/L, to greater than 300 µg/L in samples historically collected from specific monitoring wells surrounding the CEC ash landfill. Dominion Generation (Dominion) entered the Virginia Department of Environmental Quality (VDEQ) Corrective Action Program in 2002 for arsenic. While other potential constituents of concern at the site include sulfide and cobalt, arsenic is the contaminant of greatest concern and the focus of this report. Groundwater is not used for drinking water at the site. The primary source of the arsenic entering the groundwater is believed to be wet ash from former ash settling basins. The current dry ash landfill was constructed with a geomembrane liner in 1985, above the former settling basins.

The purpose of the CAP is to present a remedy that is protective of human health and the environment and complies with applicable state and federal standards pertaining to the management of solid waste. The CAP was prepared based on data included in: the Nature and Extent Study (NES)/Assessment of Corrective Measures (ACM) report (URS, 2003); the Risk Assessment (MACTEC, 2003; **Appendix A**); and a supplementary geochemical study (Battelle, 2006; **Appendix B**). The CAP was first submitted in March 2008 and was deemed technically complete January 30, 2008. The CAP was prepared in general accordance with the Virginia Department of Environmental Quality's (VQEQ) Submission Instructions No. 17 – Corrective Action Plan, Submission Instructions No. 21 – MNA-based CAMPs, and the Virginia Administrative Code 9 VAC 20-80-310.

The remedy proposed in the CAP for arsenic above the GPS is Monitored Natural Attenuation (EPA, 1999; GES, 2008a). The CAP presented the findings of an extensive, site-specific study of arsenic natural attenuation processes, and proposed a plan to confirm the reduction of arsenic concentrations in groundwater from natural attenuation. A plan for a supplemental study was included in the CAP. This report presents the results of an additional study of the natural attenuation of arsenic at the landfill.

1.1 Purpose and Objectives of the Monitored Natural Attenuation Study

In February 2010 Dominion selected AMEC Earth & Environmental (AMEC) to conduct an evaluation to:

- Expand and confirm the results of previous geochemical studies using the techniques described in the Supplemental Assessment Work Plan;
- Evaluate natural attenuation processes for arsenic at the landfill;
- Extend the area of previous studies into the river and estuary beyond the landfill;
- Conduct sediment, surface water, and groundwater sampling and analysis; and
- Present the findings with respect to arsenic natural attenuation.

1.2 Report Organization

The remainder of Section 1.0 provides site background information such as regional location, surrounding land use, historic and current operations at the facility, and physical setting. Section 1.0 also provides a brief summary of previous studies and presents the conceptual site model for the landfill. Section 2.0 describes the technical and scientific basis for the natural attenuation of arsenic in groundwater. Section 3.0 describes the techniques used in the study. Section 4.0 presents the data obtained from the effort. Section 5.0 discusses the findings derived from the data. Section 6.0 presents the conclusions in summary format.

1.3 Site Description

Site background information including regional location, surrounding land use, and historic and current operations at the facility are provided in the subsections below.

1.3.1 Regional Location and Site Features

Chesapeake Energy Center (CEC) is located beside the Southern Branch of the Elizabeth River (SBER) in the city of Chesapeake, Virginia. CEC has provided electric power for almost half a century. CEC occupies approximately 145 acres of property.

The SBER, which forms the eastern boundary of the CEC property, is the main branch of the Elizabeth River, a short tidal estuary at the southern end of the Chesapeake Bay. The SBER is highly navigated, used significantly by the military and commercial shipping, and provides numerous port facilities for the communities of Chesapeake, Portsmouth, and Norfolk, Virginia.

The City of Chesapeake is the second largest city by land area in Virginia, with a total area of 350.9 square miles. The CEC is located in the northeast portion of the City of Chesapeake, adjacent to the boundary of the Great Dismal Swamp, a wildlife refuge comprising approximately 107,000 acres.

The CEC's existing coal ash landfill is located on a peninsula in the southern portion of the CEC property. The landfill is bordered by the SBER to the east, Deep Creek to the south (estuary herein), and a non-contact cooling water channel to the west.

1.3.2 Surrounding Land Use

Adjoining land is marsh and grasslands. Various industrial facilities are located across the SBER from the landfill. The surrounding area is highly developed for commercial, industrial, and residential use. A Risk Assessment for CEC prepared by MACTEC in December 2003 found that the nearest residences were 2,000 feet to the west and up-gradient of the landfill. There are no potable water supply wells within 1,000 feet of the landfill; the local community obtains their water from public water supply lines. The shallow aquifer is not expected to ever be used as a drinking water source due to sea water intrusion and the resulting high salinity of the water.

1.3.3 Facility History

As many as three settling basins for coal ash were constructed on a peninsula that is located along the southern portion of the CEC property. This is based on data from the 1960s and 1970s. In 1985 the existing landfill was constructed over the sedimentation basins (VDEQ Solid Waste Permit No. 440).

1.3.4 Current Operations

Currently, CEC's four coal-fired generating units and eight gas turbines can generate more than 760 megawatts of electricity. Ash derived from coal combustion is disposed of at the on-site landfill. CEC exclusively utilizes the landfill for the disposal of coal ash, or coal combustion by-products. The footprint consists of approximately 22.25 acres and is lined with a 20-mil high density polyethylene (HDPE) flexible geomembrane liner.

Groundwater at the landfill is monitored by CEC to assess any changes of its quality. Groundwater monitoring has been conducted since 1984. Arsenic was reported in the uppermost (shallow) aquifer underlying the landfill at concentrations that were above the GPS (10 µg/L) during 2002. The range of arsenic concentrations in monitoring wells that were above the standard were generally between 50 and 350 µg/L.

1.4 Environmental Setting

The Environmental Setting discussion provides key background data on the CEC. Although not intended to be an exhaustive compilation of site-related data, this section generally describes the climate, geomorphology, soils, subsurface geology, surface water and groundwater in the vicinity of the CEC.

1.4.1 Climate

Climate data collected at the Norfolk Naval Air Station between 1922 and present provided by the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA) were reviewed to establish the minimum and maximum monthly average temperatures and precipitation at the site. The Norfolk Naval Air Station meteorological record station is located approximately 11 miles north of the CEC. The minimum and maximum average monthly temperatures are 35.5 °F in January and 75.0 °F in July, respectively. The minimum and maximum average monthly precipitation are 2.7 inches in February and 4.1 inches in July, respectively. The annual average rainfall between 1922 and 2009 was 39.6 inches.

1.4.2 Geomorphology

The land surface elevations of the peninsula which contains the CEC coal ash landfill range between mean sea level (MSL) and approximately 65 feet above MSL at the current crest of the landfill. The topography within the vicinity of the shoreline is steep; the land abruptly rises out of the water to an elevation between approximately 10 and 15 feet above MSL. The grade of the inland portion of the peninsula prior to land-filling activities was probably flat, with minor depressions and mounds ranging between 5 and 25 feet above MSL. Tidal marshlands are assumed to have been present over the majority of the original, undisturbed surface of the peninsula.

Fill materials, which may have contained ash from the ash-sluicing activities that predate the current landfill, were placed at and below the original grade. This remnant fill layer was capped with a geomembrane, which functions as the liner for the current landfill operations. On average, approximately 25 feet of ash is present over the geomembrane liner, and the maximum elevation of the landfill is approximately 65 feet above MSL.

1.4.3 Hydrologic Setting

The landfill is located in the Atlantic Coastal Plain physiographic province on a peninsula. Previous studies cite three water-bearing geologic units that frame the understanding of site hydrogeology: the uppermost anthropogenic unit; the Norfolk aquifer; and the underlying Yorktown confining unit. In general, groundwater flow is down through the peninsula, out under the berms, and up into the surface water system.

The upper most stratum beneath the landfill is vertically and horizontally variable and consists of construction fill (that may contain ash), buried bottom and fly ash from historic sedimentation basins, and alluvial deposits from Deep Creek and the SBER (URS, 2003). Groundwater flow velocity within the fill and reworked natural material ranges from 1.5 to 5.0 feet/year. There is a downward vertical gradient from the upper anthropogenic unit to the lower Norfolk aquifer (URS, 2003; GES 2008a, b).

Below the uppermost strata, the local geology consists of a variable layer of silty sand to sand, representing the Norfolk Formation. The Norfolk exhibits good water transmission capacity as compared to the overlying anthropogenic unit, and the underlying Yorktown confining unit. Groundwater velocities in the Norfolk sediments at the site range from 287 to 323 feet/year, with velocities decreasing with depth toward the east. The Norfolk Formation is believed to discharge to the SBER, Deep Creek, and the non-contact cooling water channel.

Tides have a variable influence on hydraulic conditions beneath the landfill. Groundwater inflow and outflow flow rates under the influence of tides are not the same. This is a hysteresis condition in groundwater response to tidal inflow and outflow; with inflow response reaching maxima in about half the time that outflows reach minima.

1.5 Key Findings of Previous Studies

In this section the key findings of previous investigations regarding the arsenic source, concentration, natural attenuation, and risk are summarized

1.5.1 Arsenic Source and Groundwater Flow

Elevated concentrations of arsenic in groundwater is attributed to leaching of legacy fill and ash contained within earthen dikes. This fill structure is on top of the formation containing the uppermost aquifer at the current landfill, the Norfolk Formation. The current, permitted, ash landfill is lined and constructed within the dikes on top of the predominantly saturated legacy fill. The site-specific conceptual model for groundwater flow was advanced by URS in 2003 and again as reported by GES in the 2008 CAP. The site conceptual model indicates that arsenic-contaminated groundwater should flow outward from the approximate center of the peninsula in a generally radial fashion from the legacy fill and ash below the current landfill liner and in the Norfolk formation, with groundwater eventually discharging to the non-contact cooling water channel (discharge canal), Deep Creek, and the SBER.

The aforementioned site-specific conceptual model for groundwater flow is simplified and does not consider effects on flow from the variable, plant-operations-dependent flow in the discharge canal, the tidally-influenced SBER, and the detention ponds at the toe of the current landfill that add complexity to the general model. The conceptual model suggests that an arsenic release signature in the surrounding surface water might be expected. However, surface water sampling has not shown the increase in arsenic concentration expected from a groundwater contribution. Instead observations suggest that, prior to discharge to surrounding waters, dissolved arsenic in the Norfolk-formation aquifer is attenuated under the naturally-occurring conditions of the subsurface beneath and around the landfill.

1.5.2 Arsenic Concentration Trend

Trend analysis has indicated that arsenic concentrations are generally decreasing (all compliance wells but one; MACTEC, 2003), indicating that arsenic flux from the site is decreasing. A plume with a decreasing contaminant mass flux is an indication of effective source control, or a decreasing source term; both are pre-conditions for a monitored natural attenuation corrective action approach.

The arsenic concentrations in groundwater are variable across the site, with the highest concentrations found in wells completed closest to the saturated fill associated with legacy disposal areas. The reduced arsenite species [As (III)] is found at 25-90% of the total arsenic concentration in groundwater, with four of the five wells sampled above 50% As(III) (GES, 2008a). The remaining groundwater arsenic is predominantly As (V), with potential for trace concentrations of organic arsenic species.

1.5.3 Natural Attenuation of Arsenic

Sediments were sampled from the Norfolk formation during well drilling (GES, 2008a) and were subjected to a battery of geochemical analyses (Battelle, 2006). Evaluation of sediment chemistry using selective extractions determined that iron oxyhydroxides on aquifer materials are adsorbing the dissolved arsenic from groundwater. Calculations determined that the amount of iron oxyhydroxides found on sediments at the edge of the landfill was insufficient to lower arsenic concentrations to below the GPS at the landfill boundary, but that dissolved arsenic attenuation will occur along the groundwater flow path if there is continued oxidation of the ample dissolved iron in the aquifer.

1.5.4 Risk Assessment

The single risk pathway identified in the risk assessment (MACTEC, 2003) was to aquatic life from groundwater discharge of arsenic to surface water. Groundwater discharge point concentrations would have to be above 1,780 mg/L before sensitive aquatic receptors would be impacted. The highest observed groundwater arsenic concentration is an order of magnitude below the surface water risk-based screening level. Adjoining surface waters were sampled during the Risk Assessment conducted in 2003. Surface waters did not exhibit arsenic concentrations above the Ambient Water Quality Criteria (AWQC), or an increase of arsenic that would be expected from a groundwater contribution.

Based on the groundwater data presented in the CAP, the constituent of concern for the CEC landfill groundwater and focus of this study is arsenic. The Norfolk Formation aquifer in the vicinity of the site is unsuitable for potable use, and future potable use is improbable.

The terrestrial biota on the landfill is considered to be limited by the large amount of human activity (i.e., heavy machinery use) and the minimal area that can provide an ecological niche. The individual song birds that do make their home on the peninsula marsh have foraging habits that preclude significant contact with the landfill slope substrate, and therefore these birds are at minimal risk.

Possible on-site receptors were identified as non-Dominion employees, Dominion employees, adjoining surface waters, and terrestrial biota living on the landfill peninsula. Access to the landfill is restricted and non-employees are kept from the premises. Additionally, CEC employees are trained to adhere to a strict health and safety policy inclusive of hazards communications and instructions for donning personal protective equipment, when appropriate. Since Dominion employees have no contact with the groundwater, and minimal contact with the landfill soil, the exposure pathway is incomplete for employees as well.

2.0 NATURAL ATTENUATION OF ARSENIC IN GROUNDWATER

The sections below contains information on arsenic aqueous chemistry and the nature of natural attenuation processes.

2.1 Overview of Process

In groundwater environments, the presence of dissolved arsenic is controlled by interaction with the aquifer solids (geomedia). The interactions are physical and chemical in nature. Arsenic species move slower than the groundwater flows. Dilution is observed because of physical mixing along the flow path and diffusion, processes not unique to arsenic. Additionally, arsenic concentration and mobility are strongly affected by specific chemical reactions with other dissolved species and geomedia. These chemical reactions can slow down, stop, or accelerate arsenic migration and concentration. Unlike organic compounds that can be mineralized (turned to CO_2 and H_2O) by reactions, arsenic cannot be destroyed by chemical processes; chemical processes cause arsenic to have a lesser or greater affinity for immobilization on geomedia. The degree and direction of arsenic attenuation depends on the geochemical environment(s) along the flow path. The balance and interaction between dissolved arsenic, the geomedia, and the other chemical constituents present in the groundwater at CEC will control the on-site and off-site groundwater arsenic concentrations.

2.2 Aqueous Geochemistry of Arsenic

Arsenic has a rich geochemistry. It is generally found in groundwater in two oxidation states, As(III) and As(V). As(V) (also known as As^{+5} or arsenate) is the more oxidized of the two species; it has lost more electrons to chemical reactions than As(III) (also known as As^{+3} or arsenite). Many elements have more than one oxidation state, forming one or more redox pairs, the As(III)/As(V) redox couple being an example. Redox reactions involve the transfer of electrons, changing the oxidation states of the participating elements.

The two redox states of dissolved arsenic each form several ionic species in groundwater, the most common being H_3AsO_4 for As(V), and H_3AsO_3 for As(III). The compounds H_3AsO_4 and H_3AsO_3 will lose protons (H^+) to become negatively charged; as a result, the solution pH decreases. H_3AsO_3 remains uncharged until about pH 9 where one H^+ disassociates to form the charged oxyanion $H_2AsO_3^{-1}$. At most groundwater pH ranges As(III) species will be uncharged. In comparison, H_3AsO_4 will begin losing H^+ at about pH 2. In most groundwater, As(V) species will be negatively charged, present again as an oxyanion. The pH controlled loss and gain of H^+ ions does not affect the oxidation state of the arsenic, only the electrostatic charge on the ion.

2.3 Arsenic Attenuation on Geomedia

The charge characteristics of arsenic species are very important with respect to transport rates. The electrostatic charges on the dissolved species interact with the charged surfaces of the geomedia, capturing and concentrating the dissolved species in a thin film on the solid's surface. At this point, captured arsenic oxyanions can covalently bond to oxide mineral surfaces, removing them from solution. The amount of arsenic that will attach to the surface is controlled by:

- The total available surface area of geomedia available for arsenic adsorption;
- The amount and type of mineral oxide, hydroxide, or oxyhydroxide forming on the geomedia surfaces;
- The oxide surface's pH-dependent charge behavior;
- The pH of the solution, as it controls arsenic speciation and electrostatic charge;
- The affinity of a specific arsenic species for a specific surface;
- The concentration and redox state of the arsenic species ($^+3$ (III) or $^+5$ (V)); and
- The presence and concentration of other dissolved ions that compete with arsenic oxyanions for a finite number of bonding sites.

These relationships have been measured for numerous individual minerals, and arsenic oxidation states, over a range of pH values with varying concentrations of competing ions. There is complex interplay and feedback between the factors listed above that suggests that they be evaluated simultaneously in order to make predictions. The end results of these processes, such as predicted arsenic in groundwater concentrations, are determined using computer programs that make the necessary calculations.

Iron and manganese oxides in soils and aquifers have been studied for over 100 years because of their ability to control the movement of nutrients. It is generally agreed that iron and/or manganese oxides in aquifers are the dominant solid phases interacting with arsenic oxyanions. It has been observed and demonstrated by several research groups, at many scales, using state of the art techniques, that:

- Iron oxides, hydroxides, and oxyhydroxides in aquifers are efficient at adsorbing arsenic, if present in sufficient quantities;
- Reductive dissolution of iron oxides, hydroxides, and oxyhydroxides releases bound arsenic and creates dissolved iron and arsenic plumes in groundwater;
- Manganese oxides are efficient at oxidizing As(III) to As(V), even in the absence of dissolved oxygen;
- As(III) cannot be oxidized efficiently by only increasing dissolved oxygen concentration; however, there is some evidence for co-oxidation of As(III) and Fe(II) by dissolved oxygen;
- The effect of species that compete with arsenic for bonding/adsorption to iron/manganese oxides cannot be neglected if accurate predictions are needed; and
- When commingled dissolved arsenic and iron plumes encounter increasing dissolved oxygen levels, iron precipitates as a metal oxide and produces continuous arsenic removal at the interface.

Previous studies have observed and measured components of arsenic natural attenuation at the CEC landfill (Battelle, 2006; GES 2008a). To further investigate the dissolved arsenic natural attenuation processes discussed above, AMEC implemented the CAP Supplemental Assessment Workplan (SAWP; GES, 2008a).

3.0 SUPPLEMENTAL ASSESSMENT WORK PLAN

The CAP SAWP (GES, 2008a) was executed with field work beginning January 27, 2010 and ending February 12, 2010. The components of the study as described in the CAP SAWP can be summarized as:

- Conduct a bathymetric study of the waters surrounding the landfill in preparation for sediment sampling.
- Collect shallow sediment samples from the discharge channel, the SBER, and the intervening estuary.
- Collect field data on the sediment samples and subsample for determination of iron and arsenic on the sediments and in the sediment pore water.
- Collect surface water samples proximal to where the sediment samples are taken and analyze for field parameters, total Fe, total As and arsenic speciation [As(III) and (V)].

A Corrective Action Monitoring Plan (CAMP; GES, 2008b) was created in parallel with the CAP. The CAMP proposed to sample four surface water locations and 18 pre-existing monitoring wells quarterly with the intent to monitor the natural attenuation of arsenic. The wells were to be sampled for the same parameters as surface water: field parameters; total Fe; total As; and arsenic speciation [As(III) and (V)]. Water level gaging would also be conducted. AMEC executed a single groundwater sampling round, as described in the CAMP, at the same time as the sediment field study.

Certain modifications were made to procedures, number of samples analyzed, and methods of study. These modifications were made due to adjustments to field conditions and/or refinement of technical approach to better accomplish the intent of the SAWP. Modifications are described in the methods and techniques descriptions that follow.

3.1 Bathymetry

A bathymetric survey of the shoreline was conducted on January 27, 2010 using a boat-mounted Odom Echotrac CVM dual-frequency transducer, a Trimble Differential Global Satellite Positioning System (GSPS), and the HYPACK data acquisition and processing package. The area surveyed included the discharge channel, the SBER adjacent to the landfill, and the connecting estuary. Survey results were geo-referenced to a state grid system, processed using the three-dimensional data visualization software SURFER, and overlain on the site map using a Geographic Information System (GIS) database developed for this project and ESRI ArcInfo GIS software. **Figure 3-1** depicts the ash landfill peninsula and the bottom contours obtained from the bathymetric survey.

3.2 Core Sampling

Core sampling methods and core sample processing are described in the following section.

3.2.1 Core Sampling Method

Core sampling was conducted to identify a geochemical transition in the sediments from a generally reducing condition to generally oxidizing. This postulated redox boundary would

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cause dissolved iron in pore water to oxidize to rust-like oxyhydroxides, binding and sequestering arsenic in pore water, and preventing arsenic discharge to surface water.

Following completion of the site bathymetry effort, the results were used to critique and adjust the core sampling locations presented in the SAWP. The bathymetry indicated that in the areas of interest in general the water was shallow (4 to 8 feet deep), with the exception of the shipping channel in the SBER. The slope of the bottom was moderate to nearly flat, with the exception of the channel cut. The original plan locations for core sampling are depicted in **Figure 3-2**, taken from the CAP. The three locations in the discharge channel were substantially retained. The most upstream locations were shifted south because of channel obstructions (skimmer nets). The three core transect locations were expanded to four, and shifted to be more proximal to monitoring well locations to enhance data analysis and correlation opportunities.

The core locations were defined as an area of operation with the goal of collecting at least three cores from each area at varied distance from the shore for examination and testing. Areas were used rather than precise locations, so that the observational approach could be used in core selection, and in recognition of the realities of core collection from small boats in a tidally influenced river. A total of seven areas—three in the channel, one in the estuary and three on the SBER side of the landfill—were chosen. Utility clearance for these areas was obtained from Dominion and the Virginia utility clearance program. The northernmost extent of the core sampling was constrained by utility crossings under the SBER. **Figure 3-3** depicts the seven selected areas and actual core locations, and their relationship to the ash landfill and the monitoring wells sampled for this effort.

The SAWP provided for selection of various coring techniques. We utilized vibrational coring (vibracore). Vibracore uses a heavy top-mounted compressed-air driven shaft with an eccentric weight to vibrate a tube into sediments. The tubing (core barrel) is fitted with a sharp-edged drive shoe and finger-type sample catcher, and is lined with an 8-mil clear polyethylene tube (liner) for sediment and pore water recovery. Two-inch nominal stainless steel drive shoes and core barrels were used. Core barrels of up to 20 ft. in length allowed collection of several feet of core in the water depths defined by bathymetry and tidal range. Aluminum pop rivets were used to secure the drive shoe to the tubing, being renewed each core. Between core sample collections, the metal tubing, drive shoe, and sample catcher had gross amounts of sediments removed with a brush and surface water, and were final rinsed with water from a locally available approved potable water supply. New polyethylene liner was used for each core recovery.

The vibracore apparatus is deployed from a small boat fitted with a forward-mount A-frame suspended over the bow. The core barrel is advanced using a gasoline-powered air compressor. A cat-head driven rope is used for lowering and hoisting the drive head and core sampler. The boat is equipped with GSPS to locate the core sites and has a boat-specific correction for the distance from the GSPS antenna to the A-frame. Aluminum poles driven by hand into the sediments and fixed to the boat are used to hold position during vibracore operation. As core samples are withdrawn from the vibracore tubing, the surface water within the liner on the top of the sediments is drained off, the top and bottom of the liner is sealed with zip-ties, and the wrapped core is laid in plastic trays for support. The location and length of the core are written with permanent marker on the core liner. A second boat was used to transport the core to a processing location, which was setup near the dock on the west side of the discharge canal.

3.2.2 Core Sample Processing

Core sample processing describes the methods used to collect field data on the vibracore samples and select and prepare sub-samples for laboratory analysis.

The natural attenuation of arsenic by precipitation on iron oxides takes place when dissolved iron reacts with oxygen. The sediment iron and arsenic data would not be representative of in situ conditions if oxidation of pore waters took place between core sampling and sediment and pore water analysis. Pore water oxidation would result in iron oxidation and precipitation, sequestering more of the arsenic from pore water than would be observed in situ, than without sampling-related oxidation. Efficient and rapid handling and preservation of the core was imperative to maintaining the integrity of the samples. The first step in prevention of sample oxidation was the use of core barrel liners sealed with zip-ties for sample containment and transport. Initially, a nitrogen-filled glove bag was used to process samples, excluding oxygen completely. Testing of core pH showed acidic conditions that inhibit iron oxidation. An overnight test of sediment and pore water oxidation revealed that visible oxidation did not take place in ~14-16 hours of normal atmospheric exposure (~21% oxygen). On longer cores, use of the glove bag for field parameter measurement more than doubled preparation time, limiting throughput and increasing exposure time during processing. Nitrogen atmosphere glove bag preparation of core was discontinued early in the program because it added unnecessary complexity.

Portable tables and a self-supporting awning were used to provide work surfaces and limited protection from sun and weather. Cores were placed on the work surface, measured, and ~1 inch slits were cut with a stainless-steel blade every 10-12 inches to allow instrument access. Probes measuring pH, oxidation-reduction potential (ORP), and conductivity were placed in sediment-pore water contact and allowed to equilibrate before logging readings. This technique is different than that specified in the SAWP, in that core sub-samples were not removed and slurried with deionized water prior to field parameter measurement. The selected method preserved core integrity prior to sub-sampling and minimized atmospheric exposure of the core and the aliquot on which field parameters were measured. Probes were cleaned with paper towels and retail distilled water between measurement points. Field instruments were calibrated according to manufacturer's instructions daily before starting processing, and checked to at least one standard at the end of the day to verify performance.

The next process was to cut the full length of the liner and split the core lengthwise using plastic putty knives. The entire core was then photographed using color-balanced high resolution macro photography. Sample intervals were selected observationally. The objective was to:

- Identify a redox boundary in the sediments where the natural attenuation of dissolved arsenic takes place;
- Preserve samples of all major geomedia types encountered;
- Span the range of observed properties based on visual observations, geomedia classification, and field parameter readings;

- Reduce the unknowns of an in-progress study; and
- Target about 40 samples for analysis.

Selected core sections were sampled using a combination of plastic putty knives and plastic spoons. Sampling equipment was decontaminated between use using potable water and Alconox laboratory detergent, rinsed with retail distilled water, and air dried. Geomedia (natural and anthropogenic sediments, and other materials of a geologic origin) on the edge, top or bottom of the core was pared away to avoid sampling material that may have been smeared or entrained during the coring process. Samples were containerized in 250 ml pre-cleaned Nalgene centrifuge bottles or in Whirl-Pak sample bags. Sampling was conducted rapidly, to avoid atmospheric exposure. Sample containers were identified using nomenclature that identified the core location and sub-sampled interval. Sediment sample freezing is recognized as a practical way to preserve iron oxidation state prior to sample analysis. Filled, cleaned, sealed, labeled, and bagged sample containers were immersed in a slurry of dry ice and isopropyl alcohol to flash-freeze the geomedia. Freezing to solid generally took less than 10 minutes of immersion. Frozen samples were kept in coolers under dry ice until laboratory processing was initiated.

3.2.3 Sediment Sample Analysis

The SAWP specifies that sediment samples and pore water samples be collected and analyzed for total iron and arsenic. All sediment extraction and analysis was conducted at the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) Wet Chemistry Laboratory. The program manager for this project directly participated in and supervised all pore water extraction and sediment sample preparation. Frozen core samples were removed from dry ice storage a few at a time and allowed to thaw in the dark at room temperature. Thawing and processing was staged so that time between removal from the cooler and processing was minimized. Following thawing, samples were centrifuged at 8000 RPM for at least 20 minutes to effect separation of pore waters form sediments. When separation was achieved, the supernatant (pore water) was withdrawn from the sample container with a polyethylene syringe. The pore water was then syringe-filtered through a 0.45-micron cassette filter, and then acidified with trace-metal grade nitric acid to pH less than 2.

Clay and silty clay samples were amenable to pore water separation by centrifugation; sands and silty sands were not. The grain-to-grain contacts in sands prevented the collapse of pore space and resulting pore water separation. Pore water from coarse-grained core samples was extracted by loading the saturated solids into a 250 or 500 ml fluoropolymer-resin Buchner funnel fitted with a Whatman #1 filter paper. Pore water was drawn from the filter and sample assembly under vacuum. After vacuum extraction, pore water samples were syringe-filtered through a 0.45-micron cassette filter, then acidified with trace-metal grade nitric acid to pH less than 2. Some entrainment of colloids below the 0.45-micron filter was noted as a very slight cloudy appearance in some samples. Pore water was successfully extracted from all core sub-samples.

The solids remaining after pore water extraction were tipped into aluminum containers (pie tins), covered with paper to prevent dusting, and allowed to air dry for several days. Samples were photographed using high resolution macro photography prior to the drying step. Having been assigned a unique sample number, a portion of each sample was taken and homogenized in a plastic container with a plastic spoon, and then dried to a constant weight in a closed desiccation vessel in preparation for chemical extraction and analysis.

Sediment samples where iron oxides had precipitated out on geomedia (exclusively sands and silty sands) were identified by color, and biased sub-sampling was performed. The objective of the biased sub-sampling was to collect aliquots of "oxidized" and "reduced" samples that would provide a better indication of the range of arsenic and iron concentrations found on geomedia within short (1-3 inches) sampling intervals. Each "oxidized" or "reduced" aliquot was assigned a unique sample number and desiccated to constant weight. All solid samples were chemically extracted using U.S. Environmental Protection Agency (EPA) Method SW-846 3051, microwave-assisted extraction with nitric acid. This extraction procedure was selected for several reasons directly related to the study goals:

- Previous work (Battelle, 2006) had indicated that the bulk of the arsenic on sediments was associated with iron oxides amenable to extraction using Method 3051;
- Previous work postulated (Battelle, 2006) that some extraction methods used would liberate arsenic from within the mineral structure of grains of geomedia; arsenic unrelated to groundwater contamination or natural attenuation processes. Method 3051 will not dissolve refractory minerals but only the coatings on the grain surface.
- Method 3051 is cited by EPA as extracting the "total environmentally available" concentration of metals bound to the surface of geomedia.
- Iron oxide extractions using Method 3051 can be used to estimate the amount of iron oxides available to participate in the natural attenuation of arsenic in sediment-water systems (Dixit and Hering, 2003; Battelle, 2006; Miller, 2000 and 2002)
- There is a wealth of information available on sediment extractions using Method 3051, including standard reference materials, which enhance the comparability of findings and regulatory acceptance of the results as representative of *in situ* conditions.

Pore waters and sediment extracts were analyzed using a combination of ICP-MS and ICP-OES techniques (EPA Methods 200.8 and 200.7). Routine detection limits of 0.002 mg/L Fe and 0.001 mg/L As were achieved. Standard reference materials, duplicates, blanks and continuous calibration verification samples were analyzed at the rate of 1:20. Results of the sediment and pore water analysis are presented in Section 4.0. No out of control events or analytical discrepancies were reported by NMBGMR. NMBGMR reported results are contained in **Appendix C**.

3.3 Groundwater and Surface Water Sampling and Analysis

Existing groundwater wells and four surface water locations at the ash landfill were used to obtain a snapshot of total iron, total arsenic, and As(III) concentrations contemporaneously with the core sampling. The following groundwater wells were proposed for sampling in the CAMP to evaluate natural attenuation progress: MW-5, MW-5D, PO-8, PO-8D, CECW-6I, CECW-6D, CECW-10, CECW-15, CECW-8, CECW-8D, PO-10, PO-10D, CECW-3, CECW-3D, CECW-2, CECW-2D, CECW-1, and CECW-1D. Attempts were made to sample all wells proposed in the CAMP. Surface water locations were approximately the same as proposed in the CAP and CAMP. The CAMP parameter list for surface water and groundwater analysis was used for the surface water and groundwater locations depicted in **Figure 3-3**.

All wells were assessed for physical condition, water level was measured from the previously surveyed top-of-casing (TOC) elevation, and total depth gauged prior to sampling. Groundwater was sampled using low flow rate (<200 ml/min final rate) techniques that monitor the stabilization of temperature, pH, conductivity, turbidity, and ORP. Parameter stabilization indicates that the water in the sampling train is representative of in situ conditions and samples can be collected. New sampling tubing was used for sampling at each well. Most wells were sampled using a peristaltic pump. When depth to water precluded the use of a peristaltic pump, Monsoon or Whale down-hole electric pumps were used. **Figure 3-4** depicts the known and inferred water table contours from measurements made during this activity.

As presented in the CAP, surface water sample selection involved use of water turbidity and sediment mobilization observations from the bathymetry study. However, the field observations during the bathymetry were unable to differentiate areas of greater or lesser turbidity at the sediment-water interface. The surface water sampling locations proposed in the CAP and CAMP were retained for this event. Surface water samples were collected using a peristaltic pump, new sample tubing, and a decontaminated tubing weight at each location. A one-gallon sample was collected in a retail distilled water jug that had been drained of its contents just prior to the surface water sampling event. The jugs were transported to shore where field parameter data were collected and logged and sub-sampling of filtered and unfiltered samples and arsenic species separation were conducted.

All water samples for laboratory analysis were containerized in laboratory-supplied, pre-cleaned polyethylene containers. Unfiltered and 0.45-micron filtered samples were collected for all wells sampled. Total iron and total arsenic samples were preserved with trace-metal grade nitric acid to pH<2. Samples were labeled with a unique identifier, bagged, and placed on ice until transferred to the laboratory for analysis. Phase Separation Science, Inc. of Baltimore, MD performed all groundwater analysis. No out of control events or analytical discrepancies were reported by Phase Separation Science, Inc. Phase Separation Science, Inc. reported results are contained in **Appendix D**.

3.3.1 Arsenic Species Field Separation

Arsenic species separation for surface water and groundwater samples was accomplished in the field using an ion exchange method modified from Edwards et al., 1998. A filtered sample is adjusted to pH between 3 and 5 using trace-metal grade sulfuric acid and is poured through the resin column. The column conditions are designed to let As(III) pass through the column while capturing As(V). The processed samples are acidified to pH<2 using trace metal grade nitric acid, given a unique identifier, bagged, and placed on ice. The sample is analyzed for total arsenic as As(III). Analysis of the collected aliquot reveals the As(III) concentration. As(V) concentration is determined by difference [As(V) = Total arsenic – As(III)]. A detailed description of the method can be found in **Appendix E**.

An oversight was made in the field application of the speciation method in that most wells (MW-5, MW-5D, PO-8D, CECW-6I, CECW-6D, CECW-15, CECW-8D, CECW-3, CECW-3D, CECW-2, CECW-2D, CECW-1, and CECW-1D) had arsenic species separation conducted on unfiltered samples. To try and gauge the impact of this oversight, the remaining wells (CECW-8, P0-8, P0-10, P0-10D) had arsenic species separation conducted on filtered and unfiltered samples.

The effect of the oversight was to reduce the precision of the estimate of the proportion of As(III) to As(V), in some wells. The overall finding regarding the general proportions of As(III) to As(V) is unchanged, As(III) is the dominant groundwater arsenic species present at the landfill. The outcome is discussed in greater detail in Sections 4.0 and 5.0 of this report.

4.0 STUDY RESULTS

The results of the study are presented here. The findings and conclusions are presented in following sections.

4.1 Bathymetry

Figure 3-1 depicts the bottom contours extending from the shoreline surrounding the ash landfill peninsula.

4.2 Vibracore Sampling

Figure 3-3 depicts the locations of the vibracore samples. **Table 4-1** presents the field parameter measurements and the analytical results obtained from the extracted samples. **Table 4-2** presents the sample locations using UTM grid locations and the total length of recovered cores. The vibracore sampling was able to recover cores from depths greater than the 1.5 feet proposed in the CAP. However, even with the greater depth the method confined sampling to the uppermost layers of the Norfolk formation. **Table 4-3** presents lithologic observations made on the dried core samples.

Figure 4-1 depicts the color range of samples obtained from cores. In general, there are four color classifications observed; dark clays and muck, light gray sand samples, gray sands mottled with iron oxide coloration, and sands completely stained with iron oxides. In the dissolved redox-reduced ferrous iron condition, iron is colorless. On reaction with oxygen the ferrous iron converts to ferric iron and immediately precipitates. These precipitated iron oxides and oxyhydroxides take on a range of yellow, orange, red and brown hues. On the basis of color alone, **Figure 4-1** indicates that iron oxides were found at some level in all cores. The analytical results bear out the importance of these visually identifiable redox conditions.

Analytical results for arsenic and iron in sediment that were classified as oxidized on the basis of color are markedly different than for reduced sediment within core subsamples, and as a group. **Figure 4-2** presents box and whisker plots for homogenized, oxidized, and reduced samples. Color-classified oxidized samples have markedly higher concentrations of iron and arsenic than reduced samples. Color is a good indicator of where natural oxidation processes are sequestering arsenic and iron from groundwater. All of the analytical results, field parameters, and selected sample photographs are presented graphically for each core in **Figures 4-3** through **4-17**.

4.3 Surface Water and Groundwater Sampling

Surface and groundwater water sampling locations are depicted in **Figure 3-3**. **Table 4-4** presents the surface water and groundwater field parameter measurements, and analytical results. The groundwater sampling event included wells that were not part of the compliance network. Non-compliance groundwater well CECW-10 was collapsed and water level could not be measured, nor sampling conducted. Non-compliance groundwater well CECW-8 yielded samples that were "black or grey". Based on the analysis of Fe, this well contained abundant iron-based filterable solids.

Table 4-5 compares two compliance rounds of sampling accomplished in 2009 with the results from this effort. In all wells common to the three sampling rounds, arsenic levels show a continued decline over time. Graphical analysis of the period of record from 2000 to 2010 is presented in **Figure 4-18.** The graphs reveal a trend towards lower concentration in the majority of wells. An upward trend is noted in the background compliance well MW-5 and the previously observed upward trend in CECW-2 is confirmed. Based on the last three rounds of sampling at CECW-2 it is possible that groundwater arsenic concentrations have peaked at this location as they are trending downward over the last 18 months. The strength of the observed downward trends are tested using statistical methods.

Previously, statistical analysis of groundwater arsenic concentration trends was conducted using Mann-Kendall non-seasonal, nonparametric analysis of the 1999-2006 period of record (GES 2008a). Wells CECW-1, CECW-2, CECW-3, CECW-5, CECW-6, MW-5, PO-8, PO-9, and PO-10 were evaluated in 2006; no adjustments were made for seasonality or yearly averages taken. The trend analysis (GES 2008a, Attachment H) revealed that the majority of compliance wells have negative slope regressions (arsenic concentrations trend downward) and negative Mann-Kendall S statistics (the trend is constant over time). CECW-2 and MW-5 did not follow the trend. The 1999 through 2006 arsenic data set for the CEC Landfill compliance wells were used to calculate a time range for GPS achievement (GES 2008a). The minimum period to achieve the GPS was calculated to be 4.1 years for PO 9, the maximum at 17.4 years for PO 10. A median value of 6.3 years to achieve the GPS, with no action, was determined.

Similar to the previous efforts using Mann-Kendall analysis, trends were evaluated for groundwater arsenic concentrations over the period 2000-2010. **Table 4-6** presents the Mann-Kendall analysis conducted as part of the current effort. As was found previously, the Mann-Kendall S statistic was again negative for all wells but MW-5 and CECW-2, indicating a decreasing trend that is constant over time. A two-tailed p-test was used to evaluate the strength of the Mann-Kendall test and the results are presented in the table. From **Figure 4-18**, and **Table 4-6,** it can be seen that as groundwater concentrations approach the GPS of 10 µg/L, slopes decrease to near-zero values. Calculation of time to achieve GPS is not as meaningful when the data and groundwater background arsenic concentrations drive near-zero slope factors.

Additional Mann-Kendall evaluation was made of the seasonality of the data. The Mann-Kendall S statistic is again negative for all seasons, indicating the overall strength of the generally observed downward trend. The p-test evaluation shows less certainty for the summer and winter events because they have the least number of samples taken. When the totality of all data 2000-2010 for all compliance wells is evaluated, the most strongly negative Mann-Kendall S observed in the data set, -76, is calculated (**Table 4-6**, *Seasonal Tests, All Categories*). The seasonal Mann-Kendall test indicates that little seasonal influence is observed in the arsenic data, and the overall trend of the arsenic in groundwater concentrations at the CEC landfill is consistent and towards decreasing values.

4.4 Groundwater Elevation

Table 4-7 presents well construction details and locations. **Figure 3-4** depicts the known and inferred water table contours in the uppermost anthropogenic unit and the Norfolk Formation. The radial flow from the landfill noted by previous investigators was confirmed.

4.5 Arsenic Speciation of Groundwater and Surface Water

As(III) concentrations are presented in **Table 4-8** as concentrations and percentage of total arsenic. Wells farther from the ash fill tend to have As(III) concentrations lower than wells screened close to the landfill. This indicated that some oxidation of As(III) is taking place. **Figure 4-19** depicts the relationship between As(III) and total arsenic. There are weak trends towards higher As(III) percentage of total arsenic with increasing total arsenic concentration. This is the expected relationship because the highest arsenic concentrations are in the ash fill material and the processes that attenuate the plume with distance also provide pathways for As(III) to be oxidized to As(V).

As described in Section 3.3.1, due to oversight, most wells had arsenic species separation conducted on unfiltered samples. Wells CECW-8, PO-8, PO-10, and PO-10D had field arsenic species separation conducted on filtered and unfiltered samples. This change in procedure was done to evaluate the effect of conducting speciation on unfiltered samples rather than the generally preferred filtered samples. The difference between filtered and unfiltered samples field speciated for arsenic varied from +13% (filtered sample higher) to -30% (filtered sample lower). The differences observed in the filtered vs. unfiltered arsenic speciation results are due to the role of dissolved iron, or particulates, and in the processing method. There is some additional uncertainty introduced in the processing and analysis, as evidenced by As(III) concentrations that are greater than 100% of the total arsenic determination. The ion exchange method has good repeatability when particulates or dissolved iron are not involved. As(III) is the dominant arsenic species close to the landfill, with As(V) becoming the dominant species farther from the landfill.

5.0 DISCUSSION OF FINDINGS

In this section, analysis of the data collected is presented and discussed in the context of natural attenuation of arsenic.

5.1 Groundwater and Surface Water Chemistry

Groundwater and surface water sampling and analysis confirmed the major points of previous studies. The highest concentrations of arsenic are found in the uppermost strata at the site, the anthropogenic unit where coal combustion by-products were placed. Arsenic concentrations in most wells sampled were above the GPS of 10 µg/L. There is a background arsenic signature present in the 'upgradient' monitoring wells that increases with depth (MW-5 5.5 µg/L vs. MW-5D 8.8 µg/L).

The arsenic speciation in groundwater found during this effort also confirmed the results of previous studies. Within and beneath the landfill the dominant arsenic species in groundwater is As(III) with the ratio of As(III) to As(V) decreasing with distance from the landfill (**Figure 4-19**). Within the immediate vicinity of the landfill As(III) accounts for as much as 100% of the detectable arsenic. The furthest groundwater samples from the landfill showed that As(V) becomes dominant with As(III) accounting for a lesser fraction, as low as 13% in one case. The finding that arsenic is being oxidized at it moves away from the landfill is favorable for MNA, as oxidized As(V) is preferentially adsorbed to iron oxides as compared to reduced As(III).

Comparison of current results with historic dissolved arsenic data shows that dissolved arsenic concentrations are decreasing with time. Arsenic concentrations also decrease with distance from the saturated legacy fill and ash (**Figure 5-1** and **5-2**). The increase of the oxidation state of arsenic with distance from the source is observed where well configurations allow assessment. Natural attenuation is decreasing groundwater arsenic concentration through a known mechanism and the mass of the arsenic dissolved in groundwater is decreasing with time. As discussed previously, observed decrease in source term is an essential component of a monitored natural attenuation demonstration.

Surface water arsenic concentrations are highest at SW-2 and SW-3 at the south end of the landfill. This is inconsistent with the shorter landfill to surface water pathway in the cooling water channel than in the SBER and Deep Creek estuary. The result could be due to greater attenuation of arsenic, differences in source concentrations, preferential flow paths, or other unknown factor(s). Surface water As(III) concentrations vary from 70% to 82%. This is different from the much lower As(III) groundwater concentrations in wells farther from the landfill. It is possible that surface water arsenic and landfill groundwater arsenic are unrelated in their source.

Comparison between filtered and unfiltered groundwater samples for arsenic and iron show that on average the filtered samples are 3% to 4% lower in concentration than unfiltered. The correlation is very good with R^2 values near unity (0.99). A small portion of the arsenic and iron in the groundwater is associated with filterable solids. This is not unexpected as many of the monitoring wells yielded samples with measureable (>1.0 NTU) turbidity.

The trends in filtered surface water are not the same as in groundwater. At the south end of the landfill the filtered arsenic and iron surface water concentrations show more variation than in groundwater, up to 49% decrease in arsenic and a 74% decrease in iron. The other two surface water samples show less variation with a 0% to 24% change in arsenic and a 27% to 35% change in iron, but are still significantly different from the groundwater condition. No surface water sample taken to date has been above the Virginia water quality criteria for aquatic receptors of 36 µg/L.

5.2 Sediment and Pore Water Chemistry

Sediment and pore water chemistry indicate that arsenic is being removed from groundwater by reaction with iron oxides (rust) on the geomedia (sands) of the Norfolk Formation. Dissolved iron in the groundwater forms rust when it reacts with oxygen, the rust reacts with arsenic in groundwater, removing it from groundwater by forming a stable solid. The dissolved arsenic and iron – oxygen – rust system present beneath the waters of SBER, the estuary, and the discharge channel are actively removing arsenic from groundwater. This is evidenced by the observed sediment and pore water chemistry.

Examination of the data on a core-by-core basis (**Figure 4-3** through **Figure 4-17**) does not reveal readily apparent vertical trends in the data collected. The lack of vertical trends is due to few samples being collected in reduced zones of the Norfolk Formation; the sampling did not extend below the upper zone of attenuation which is dominated by oxidized sands. This lack of sampled evidence for attenuation in the vertical is borne out by statistical and graphical analysis of pore water and sediment arsenic and iron concentrations; again, statistics do not show good correlations with depth of sampling. The sampling was confined to the upper few feet of the Norfolk Formation, so the potential range of vertical variation in sediment chemistry was not assessed. What is clear is that:

- The majority of the sediments sampled are oxidized;
- Upper sands are dominated by iron coated geomedia; and,
- Iron-oxide-coated geomedia is actively attenuating arsenic concentrations in pore water.

The clay/peat samples (predominantly comprising a top layer in the cores, over the sands) do not provide information on the geomedia where the majority of groundwater flow occurs, namely, in the sands. Restricting further data analysis to sands provides more insight to the processes taking place at the landfill.

The horizontal distribution of sediment and pore water chemistry provides the strongest evidence developed to date for the natural attenuation of arsenic by subsurface formation of iron oxides and oxyhydroxides. There is an obvious trend in arsenic sequestration by natural attenuation when the sediment and pore water data are evaluated with respect to distance from the shoreline and landfill. **Figure 5-1** depicts this relationship for pore waters and **Figure 5-2** illustrates the observed geomedia condition. The decrease in iron geomedia concentrations is weaker than the pore water relationship, but this actually bodes well for continued sequestration of arsenic as it indicates that there are ample amounts of iron oxides and oxyhydroxides available at some distance from the landfill. The concentrations of arsenic decrease markedly in both pore water and sandy geomedia with distance from the landfill.

Arsenic and iron ratios on geomedia were calculated. The relationship was found to be bimodal. Below arsenic concentrations of ~2000 µg/kg the median As/Fe ratio (as µg/mg) was

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found to be 0.39 (mean of 0.42). Above ~2000 µg/kg the median As/Fe ratio doubled to 0.81 (mean of 0.91). Increasing iron and arsenic concentration favors increased efficiency of arsenic sequestration.

6.0 CONCLUSIONS

Based on the results from this study and review and comparison with previous study efforts, AMEC has concluded the following:

Arsenic concentrations in groundwater at the landfill are decreasing with time and with distance from the source (the legacy ash and fill). The shrinking source term allows a Monitored Natural Attenuation remedial action approach for the CEC Ash Landfill.

The dominant arsenic species in the landfill source is As(III). As(III) percentages decrease away from the landfill indicating that natural oxidation of As(III) to As(V) is taking place. Decreasing As(III) concentrations favor a Monitored Natural Attenuation remedial action because As(V) binds more readily to iron oxides and oxyhydroxides than As(III).

Sampling and analysis of pore water and geomedia from cores obtained from beneath surface water bodies indicate that arsenic concentrations decrease with distance from the landfill. Arsenic sequestration on iron-bearing geomedia is attenuating dissolved arsenic concentrations outside the landfill and peninsula boundaries.

Processes that would inhibit the continued natural attenuation of arsenic outside the landfill were not found. Natural attenuation of arsenic at the CEC Ash Landfill is taking place; Monitored Natural Attenuation is a viable remedial alternative for the CEC Ash Landfill.

7.0 REFERENCES

GES, 2008a. Corrective Action Plan - Dominion Generation Chesapeake Energy Center Ash Landfill, Chesapeake, VA, Solid Waste Permit No. 440, Groundwater and Environmental Services of NC, February 2008.

GES, 2008b. Corrective Action Monitoring Plan - Dominion Generation Chesapeake Energy Center Ash Landfill, Chesapeake, VA, Solid Waste Permit No. 440, Groundwater and Environmental Services of NC, February 2008.

Hirsch, R.M. and J.R. Slack (1984). A non-parametric trend test for seasonal data with serial dependence. Water Resources Research, 20, 727–732.

Libiseller, C. and A. Grimvall (2002). Performance of partial Mann-Kendall test for trend detection in the presence of covariates. Environmetrics, 13, 71-84.

MACTEC, 2003. Risk Assessment for Chesapeake Energy Center.

Miller, G. P., 2000. Prediction of the Environmental Mobility of Arsenic: Evaluation of a Mechanistic Approach to Modeling Water-Rock Partitioning. EPRI, Palo Alto, CA 2000. 1000547.

Miller, G. P., 2002. Prediction of the Environmental Mobility of Arsenic: Selection and Use of Partitioning Coefficients. EPRI, Palo Alto, CA 2002. 1005308.

Sen, P.K. (1968). Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association, 63, 1379-1389.

URS, 2003. Assessment of Corrective Measures Report, 2003. Dominion Generation's CEC Industrial Landfill, Chesapeake, Virginia.

TABLES

TABLE 4-1. CORE FIELD PARAMETERS AND ANALYTICAL RESULTS

Core	Depth (in)	pH Standard Units	Oxidation Reduction Potential mV	Conductivity (mS/cm)	Depth Interval (in)	Dissolved Arsenic (µg/L)	Dissolved Iron (mg/L)	Solid Extracted Arsenic (mg/kg)	Solid Extracted Iron (mg/kg)
1A	0	5.85	1	3.3	0-2	41	0.085	0.761	1713
1A	10	6.39	-235	5.1	12-15	24	0.011	0.262	1224
1A	20	6.8	-165	2.7	24-27	37	0.007	0.460	1164
1A	30	6.34	-182	1.4	38-40	41	ND	1.057	2161
1A	40	6.29	-140	2.2					
1B	0	5.76	-309	7.4	6-9	50	0.007	8.242	37176
1B	10	6.54	-308	10.1	40-43	34	ND	4.221	11227
1B	20	6.63	-357	6.6	49-53	181	0.012	0.645	2673
1B	30	6.73	-356	6.4					
1B	40	6.75	-288	6.2					
1B	50	6.92	-361	2.6					
1C	0	5.74	50	3.1	6-9	39	0.004	0.264	1039
1C	10	6.99	116	4.8	30-33	38	0.959	1.260	3362
1C	20	6.81	82	4					
1C	30	6.44	50	3.1					
1C	37	6.5	11	3					

TABLE 4-1. CORE FIELD PARAMETERS AND ANALYTICAL RESULTS (cont.)

Core	Depth (in)	pH Standard Units	Oxidation Reduction Potential mV	Conductivity (mS/cm)	Depth Interval (in)	Dissolved Arsenic (µg/L)	Dissolved Iron (mg/L)	Solid Extracted Arsenic (mg/kg)	Solid Extracted Iron (mg/kg)
2A	0	5.33	86	7.5	9-12	452	0.018	1.199	1116
2A	10	6.14	65	5	43-46	102	0.008	0.982	2172
2A	20	6.46	109	4.4					
2A	30	6.83	96	1.6					
2A	40	6.21	27	3.2					
2A	48	6.21	87	1.8					
2B	0	5.49	123	3.3	0-4	173	0.012	1.510	3129
2B	10	6.29	95	3.6	10-14	147	0.034	0.836	1214
2B	20	6.12	73	2.2	28-32	54	0.081	0.632	1091
2B	30	7.31	196	0.6	40-43	33	0.004	1.474	2643
2B	40	6.29	103	1.6					
2B	45	6.41	38	1.3					
2C	0	6.19	-234	2.7	14-16	39	0.142	0.996	2852
2C	10	6.45	33	4	28-32	34	12.700	0.461	1612
2C	20	6.3	80	2.1	43-46	36	0.581	5.165	4834
2C-dup	30	6.68	90	1	43-46			20.090	10490
2C-dup	40	6.64	83	0.6	43-46			1.400	3621
2C	45	6.02	106	5.4					

TABLE 4-1. CORE FIELD PARAMETERS AND ANALYTICAL RESULTS (cont.)

Core	Depth (in)	pH Standard Units	Oxidation Reduction Potential mV	Conductivity (mS/cm)	Depth Interval (in)	Dissolved Arsenic (µg/L)	Dissolved Iron (mg/L)	Solid Extracted Arsenic (mg/kg)	Solid Extracted Iron (mg/kg)
3C	0	6.39	-276	11.7	10-12	37	0.033	7.873	38166
3C	10	6.72	-325	15	24-27	36	ND	6.176	31072
3C	20	7	-347	13.8					
3C	30	6.88	-346	11.8					
3C	40	7.68	-346	7.3					
3C	50	6.86	-366	9.4					
3C	60	6.97	-350	8.7					
4A	0	6.52	-306	8.5	12-14	59	ND	0.305	2135
4A	10	6.53	-352	13.3	23-24	32	0.485	0.706	3513
4A	20	6.49	-277	13	30-33	36	4.304	1.634	6941
4A	30	6.53	-37	3.5					
4A	40	6.5	-44	7					
4B	0	5.57	-285	10	19-21	29	ND	0.706	3513
4B	10	6.57	-368	12.4	48-50	49	0.042	1.634	6941
4B	20	6.93	-346	11.5					
4B	30	6.96	-340	10.3					
4B	40	6.76	-338	10.1					
4B	50	6.63	-304	8.8					
4B	60	6.7	-285	7.6					
4C	0	6.9	-239	9.4	0-3	38	0.074	4.952	22611
4C	10	6.83	-348	7.9	30-34	16	4.195	4.180	24728
4C	20	6.81	-301	6.4					
4C	30	6.64	-123	3.7					
4C	40	6.59	-74	3.4					
4C	50	6.68	-49	1.6					
4C	60	6.70	-48	1.2					

TABLE 4-1. CORE FIELD PARAMETERS AND ANALYTICAL RESULTS (cont.)

Core	Depth (in)	pH Standard Units	Oxidation Reduction Potential mV	Conductivity (mS/cm)	Depth Interval (in)	Dissolved Arsenic (µg/L)	Dissolved Iron (mg/L)	Solid Extracted Arsenic (mg/kg)	Solid Extracted Iron (mg/kg)
Test 5A	0	5.14	-68	1.3					
Test 5A	5	6.38	-400	3.2					
Test 5A	10	6.47	-369	7.7					
Test 5A	15	6.41	-392	7.7					
Test 5B	0	6.64	-97	1.8					
Test 5B	5	7.05	-79	5.2					
Test 5B	10	6.98	-150	4.3					
Test 5B	15	7.04	-28	3.5					
6A	5	6.35	-50	6.9	10-12	44	19.150	4.837	5927
6A-dup	10	6.29	-15	4	10-12			6.533	7991
6A-dup					10-12			3.135	5061
6B	0	6.17	37	5.9	0-3	202	1.222	1.667	3144
6B	5	6.04	103	5.2	12-14	28	1.987	3.376	4181
6B-dup					12-14			5.494	8276
6B-dup					12-14			3.317	6483
6B	10	5.98	114	4.2	23-25	31	0.495	3.374	5988
6B-dup					23-25			4.542	6487
6B-dup					23-25			2.511	5378
6B	15	6.56	99	2.4	30-32	32	0.815	5.044	6102
6B-dup	20	6.04	94	4.8	30-32			7.151	9273
6B-dup	25	5.93	113	3.7	30-32			2.183	6225
6B	30	5.76	78	2.8					
6B	35	6.27	100	5.9					

TABLE 4-1. CORE FIELD PARAMETERS AND ANALYTICAL RESULTS (cont.)

Core	Depth (in)	pH Standard Units	Oxidation Reduction Potential mV	Conductivity (mS/cm)	Depth Interval (in)	Dissolved Arsenic (µg/L)	Dissolved Iron (mg/L)	Solid Extracted Arsenic (mg/kg)	Solid Extracted Iron (mg/kg)
7A	0	6.39	-276	11.7	0-2	217	10.218	19.891	4558
7A	5	6.72	-325	15	7-9	196	0.061	17.207	4626
7A	8	7	-347	13.8	11-13	86	0.039	8.166	2707
7A	12	6.88	-346	11.8	13-16	68	0.005	6.854	3074
7A	15	7.68	-346	7.3					
7A	18	6.86	-366	9.4					

TABLE 4-2. CORE UTM LOCATIONS AND RECOVERY

ID	Sample Type	Total Recovery (ft)	Easting (m)	Northing (m)
1A	Core	3.60	383939	4069595
1B	Core	4.33	383931	4069592
1C	Core	3.50	383964	4069616
2A	Core	3.75	383927	4069316
2B	Core	3.90	383947	4069319
2C	Core	4.00	383966	4069319
3A	Core	5.00	383963	4069035
3B	Core	4.60	383963	4069029
3C	Core	5.20	383973	4069023
4A	Core	3.30	383732	4069068
4B	Core	5.60	383719	4069050
4C	Core	5.40	383690	4069024
Test 5A	Core	1.70	383516	4069305
Test 5B	Core	1.40	383509	4069334
6A	Core	3.00	383556	4069510
6B	Core	1.25	383558	4069509
7A	Core	1.50	383613	4069662
SW-1	Surface Water	N/A	383609	4069695
SW-2	Surface Water	N/A	383610	4069234
SW-3	Surface Water	N/A	383937	4069222
SW-4	Surface Water	N/A	383946	4069594
Projection: UTM Zone 18S		**Datum: WGS84**		

Electronic Filing: Received, Clerk's Office 09/24/2020

Quartz Sand with 1% dark minerals	7.5 YR 4/2	-1 to 2	Angular-subangular	Poor	<2% Dark minerals.
Fine quartz	7.5 YR 3/2	.5 to 2.0	Angular-subangular	Well	
Quartz sand	10 YR 3.5/2	0.0 to 2.0	Angular-subangular	Poor	Slight mottling of dark
Quartz sand	2.5 Y 6/3	3mm to 2.5		Very poor	Mottled with iron stai
Silty fine quartz sand	Mottled: 10 YR 7/1 to 10 YR 5.5/1	0.0 to 4.0		Very Poor	Some organic mottlin grains clay coated.
Peat with 2% quartz grains	10 YR 2/1 to 10 YR 2/2	1.0 to 3.0	Well rounded		Black to very dark.
Clay	2.5 Y 4/1				Slightly silty dark-gra
Fine sand	2.5 Y 6/2 to 2.5 Y 5/2	1.0 to 2.5	Subangular - subrounded	Poor	Clay coated grains, tr
Quartz sand	10 YR 6/3	0.0 to 2.0		Poor	Organic clay partings coating.
Quartz sand	2.5 Y 7/2 to 2.5 Y 6/2	-1.0 to 1.5		Very Poor	Clay coated grains, 1-
Quartz sand		1.5 to 2.5	Subangular	Moderate	Clay coated grains, tr
Very fine quartz sand	10 YR 5/2	1.5 to 2.0	Angular - subangular	Well	<1% organic mater fr
Quartz sand	2.5 YR 4/2	1.5 to 2.5	Angular	Well	Occasional large orga
Fine quartz sand	2.5 Y 5/3	0.0 to 3.5	Angular - subrounded	Very Poor	Clay coated grains, 2 color.
Quartz sand	2.5 Y 7/3 to 2.5 Y 8/1	1.5 to 2.5		Moderate	Trace dark minerals, slightly mottled.
Quartz sand w/ silty sand lenses	Mottled: 10 YR 7/1 to 10 YR 6/6	6mm to 2	Angular - subangular	Poor	Mottled silty sand len trace clay.
Fine quartz sand	Mottled: 10 YR 6/6 to GLEY 8/N	2.0 to 4.0	Angular	Poor	<1% dark minerals.
Quartz sand with lithic fragments	Mottled: 10 YR 6/6 to 10 YR 6/3	8mm to 3.0		Very Poor	
Quartz sand	2.5 Y 7/1	0.5mm to 2.5		Very Poor	Clay coated grains, 2 color.
Silty Clay	2.5 Y 4/1 Dark Gray				Structureless in samp
Clay	2.5 Y 4/1			Well	Slightly silty dark-gra
Very fine quartz sand	2.5 YR 3/1	1.0 to 2.0	Angular	Poor	Matrix made up of da
Quartz sand	2.5 YR 7/2	0.0 to 2.5	Subangular - subrounded	Poor	2% organic fragment
Fine quartz sand		0.0 to 2.0	Subangular - rounded	Poor	Organic clay partings organic fragments.
Clay	2.5 Y 4/1			Well	Slightly silty dark-gra
Clay	2.5 Y 4/1				Slightly silty.
Clay with minor silt	2.5 Y 8/4	<4.0			
Fine sand	Mottled: GLEY 8/N white to 10 YR 6/6	0.0 to 3.5		Very Poor	
Fine quartz sand	10 YR 3/4	1.0 to 2.5		Poor	Iron staining, shell fra
Very fine quartz sand	Mottled: 10 YR 6/6 to GLEY 8/N	2.5 to 3.0	Angular - subangular	Well	1-2% dark minerals.
Quartz sand	Overall: 2.5 Y 7.5/6, Mottling: 2.5 Y 8/2 to 7.5 YR 5/8	-1.0 to 4.0	Subangular - subrounded	Very Poor	Strongly mottled, abu grains.
Fine sand	2.5 Y 7.5/6 to 7.5 YR 5/8	2.0 to 4.0 w/15% <4.0		Poor	Strongly mottled silty
Quartz sand	2.5 Y 8/1 to 2.5 Y 6/2	-1.0 to 3.0	Subangular - subrounded	Poor	Clay coated grains, 1-
Fine quartz sand	5Y 7.5/2.5		Subangular - subrounded	Very Poor	Trace dark mineral to
Quartz sand	Mottled: 2.5 Y 6/1 to 2.5 Y 5/2	1.0 to 2.5	Angular - subangular	Poor	>2% Dark minerals.
Quartz sand	2.5 Y 7.5/4 to 2.5 Y 7.5/1	-1.0 to 2.5		Very poor	Clay coated grains, <

Electronic Filing: Received, Clerk's Office 09/24/2020

	Turbidity (NTU)	Temperature (°C)	Conductivity (mS/cm)	pH Standard Units	TDS (g/L)	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	Total Arsenic (µg/L)	Arsenic (III) (µg/L)	Iron (µg/L
ater	7.6	13.88	12.2	6.81	7.58	0	-34	35	34	7600
ater	7.6	13.88	12.2	6.81	7.58	0	-34	33		7100
ater	9.6	17.58	26.8	6.64	16.6	0	15	19	20	1000
ater	9.6	17.58	26.8	6.64	16.6	0	15	17		9300
ater	3.9	13.87	25.1	6.71	15.5	0	-100	14	2.2	1000
ater	3.9	13.87	25.1	6.71	15.5	0	-100	3.9		84
ater	4.9	16.79	25.9	6.7	16.1	0	-17	21	21	1600
ater	4.9	16.79	25.9	6.7	16.1	0	-17	20		1500
ater	4.5	12.68	3.77	7.06	2.41	3.65	89	11		1200
ater	4.5	12.68	3.77	7.06	2.41	3.65	89	5	1.3	52
ater	9.3	17.56	25.9	7.34	16	0	-109	130	110	1700
ater	9.3	17.56	25.9	7.34	16	0	-109	120		1300
ater	5.6	18.51	19.1	5.64	11.8	1.91	100	25	19	1400
ater	5.6	18.51	19.1	5.64	11.8	1.91	100	23		1400
ater	2.9	18.14	8.97	6.75	5.67	0	-69	210	210	1500
ater	2.9	18.14	8.97	6.75	5.67	0	-69	210		1500
ater	148	11.08	0.018	5.49	0.011	5.47	-223	8.7	1.1	2700
ater	148	11.08	0.018	5.49	0.011	5.47	-223	6.1	1.1	310
ater	6.9	13.71	13.9	6.33	8.59	0	36	20	9.4	1800
ater	6.9	13.71	13.9	6.33	8.59	0	36	12	1.1	1800
ater	95.9	15.59	0.019	6.42	0.012	8.43	-39	11	2	120
ater	95.9	15.59	0.019	6.42	0.012	8.43	-39	9.9	1.7	75
ater	5.8	16.97	2.09	6.59	1.34	0.02	78	9.4	1.3	2300
ater	5.8	16.97	2.09	6.59	1.34	0.02	78	4.2		1000
ter	0	10.41	28.8	6.94	17.9	0	8	64	49	1000
ter	0	10.41	28.8	6.94	17.9	0	8	58	36	880
ter	0	15.93	27.9	7.19	17.3	0	-52	57	50	1100
ter	0	15.93	27.9	7.19	17.3	0	-52	55	57	960
ter	2.8	12.86	0.383	6.08	0.249	0	211	3.5	0.7	570
ter	2.8	12.86	0.383	6.08	0.249	0	211	3.2		40
ter	5.4	17.43	2.89	6.1	1.9	1.25	3	8.8	9.3	16000
ter	5.4	17.43	2.89	6.1	1.9	1.25	3	8.8		16000
ter	0	15.18	26.5	4.89	16.4	0	237	2	2.2	3200
ter	0	15.18	26.5	4.89	16.4	0	237	2.2		3100
ter	0	15.18	26.5	4.89	16.4	0	237	2.3	2.4	3100
ter	0	15.18	26.5	4.89	16.4	0	237	2.3		3000
ater	8.8	8.8	9.01	7.33	5.62	10.33	-170	1.3		910
ater	8.8	8.8	9.01	7.33	5.62	10.33	-170	1	0.7	590
ater	15.5	8.94	9.43	7.36	5.94	9.96	-168	2.6		1,100
ater	15.5	8.94	9.43	7.36	5.94	9.96	-168	1.7	1.4	550
ater	45.3	7.42	5.28	7.21	3.33	10.48	-167	2.7		2,900

TABLE 4-5. TIME-DEPENDENT ARSENIC CONCENTRATION IN GROUNDWATER

Well	Arsenic (mg/L) 10-Mar-09	Arsenic (mg/L) 15-Sep-09	Arsenic (mg/L) 12-Feb-10
MW-5	0.008	0.005	0.0035
CECW-1	0.062	0.051	0.035
CECW-2	0.097	0.032	0.014
CECW-3	0.014	0.010	0.011
CECW-6I	0.345	0.317	0.210
PO-8	0.022	0.018	0.011
PO-10	0.110	0.135	0.064

TABLE 4-6. MANN-KENDALL TREND ANALYSIS FOR NINE MONITORING WELLS

Location	Mann-Kendall *S*	p-value (two sided)	Slope (mg/L-year)	Trend	Last As Test (mg/L)
CECW-1	-19	0.1391	-0.0044	Down+	0.035
CECW-2	28	0.0288	0.0068	Up+	0.014
CECW-3	-35	0.0064	-0.0073	Down+	0.011
CECW-5	-15	0.1715	-0.0011	Down*	0.0035
CECW-6	-9	0.0909	-0.0448	Down*	0.067
MW-5	24	0.0302	0.0004	Up*	0.004
PO-8	-14	0.2743	-0.0007	Down	0.011
PO-9	-16	0.1508	-0.0005	Down*	0.018
PO-10	-13	0.3115	-0.0015	Down	0.064
Seasonal Tests					
Spring	-13	0.6811	0.0000	Down	
Summer	-5	0.3173	-0.0050	Down*	
Fall	-45	0.1901	-0.0005	Down	
Winter	-13	0.1730	-0.0051	Down*	
All categories	-76	0.1181	-0.0003	Down	

* weak p-test
+ strong p-test

TABLE 4-7. WELL CONSTRUCTION AND LOCATIONS

			2010 CAMP		**GES-January 2006**	
ID	**Easting (m)**	**Northing (m)**	**Depth to Water (ft)**	**Total Depth (ft)**	**Depth to Water (ft)**	**Total Depth (ft)**
PO-10D	383888	4069130	3.59	28.94	3.45	28.85
PO-10	383888	4069129	2.92	12.75	2.47	12.35
CECW-8D	383908	4069073	3.71	30.35	3.63	32.35
CECW-8	383924	4069016	2.87	7.52	2.8	7.57
CECW-15	383740	4069091	6.42	35.15	4.75	32.25
CECW-10	383741	4069100	Dry	4.61	4.27	12.75
CECW-2	383904	4069307	17.19	26.85	17.27	25
CECW-2D	383903	4069302	19.85	45.83	15.91	45.8
CECW-3	383777	4069282	11.63	25.39	11.85	25.4
CECW-3D	383776	4069283	14.85	46.09	14.92	45.9
CECW-6D	383592	4069528	20.55	45.54	20.17	44.4
CECW-6I	383591	4069529	20.53	34.18	19.67	34.15
PO-8D	383671	4069761	21.83	48.29	21.31	47.9
PO-8	383648	4069749	12.49	18.74	11.32	18.7
MW-5	383838	4070118	8.29	16.91	9.31	16.88
MW-5D	383839	4070119	7.97	33.03	8.9	32
CECW-1D	383906	4069617	20.79	53.16	20.02	51.65
CECW-1	383907	4069614	10.76	27.69	14.52	27.2
Projection: UTM Zone 18S		**Datum: WGS84**				

TABLE 4-8. As(III) AS A PERCENTAGE OF TOTAL ARSENIC

ID	As (ug/L)	As(III) (ug/L)	As(III) %
CECW-1	35	34	97%
CECW-1D	19	20	105%
CECW-2	14	2.2	16%
CECW-2D	21	21	100%
CECW-3-F	5	1.3	26%
CECW-3D	130	110	85%
CECW-6D	25	19	76%
CECW-6I	210	210	100%
CECW-8	8.7	1.1	13%
CECW-8-F	6.1	1.1	18%
CECW-8D	20	9.4	47%
P0-8	11	2	18%
P0-8-F	9.9	1.7	17%
P0-8D	9.4	1.3	14%
P0-10	64	49	77%
P0-10-F	58	36	62%
P0-10D	57	50	88%
P0-10D-F	55	57	104%
MW-5	3.5	0.7	20%
MW-5D	8.8	9.3	106%
CECW-15	2	2.2	110%

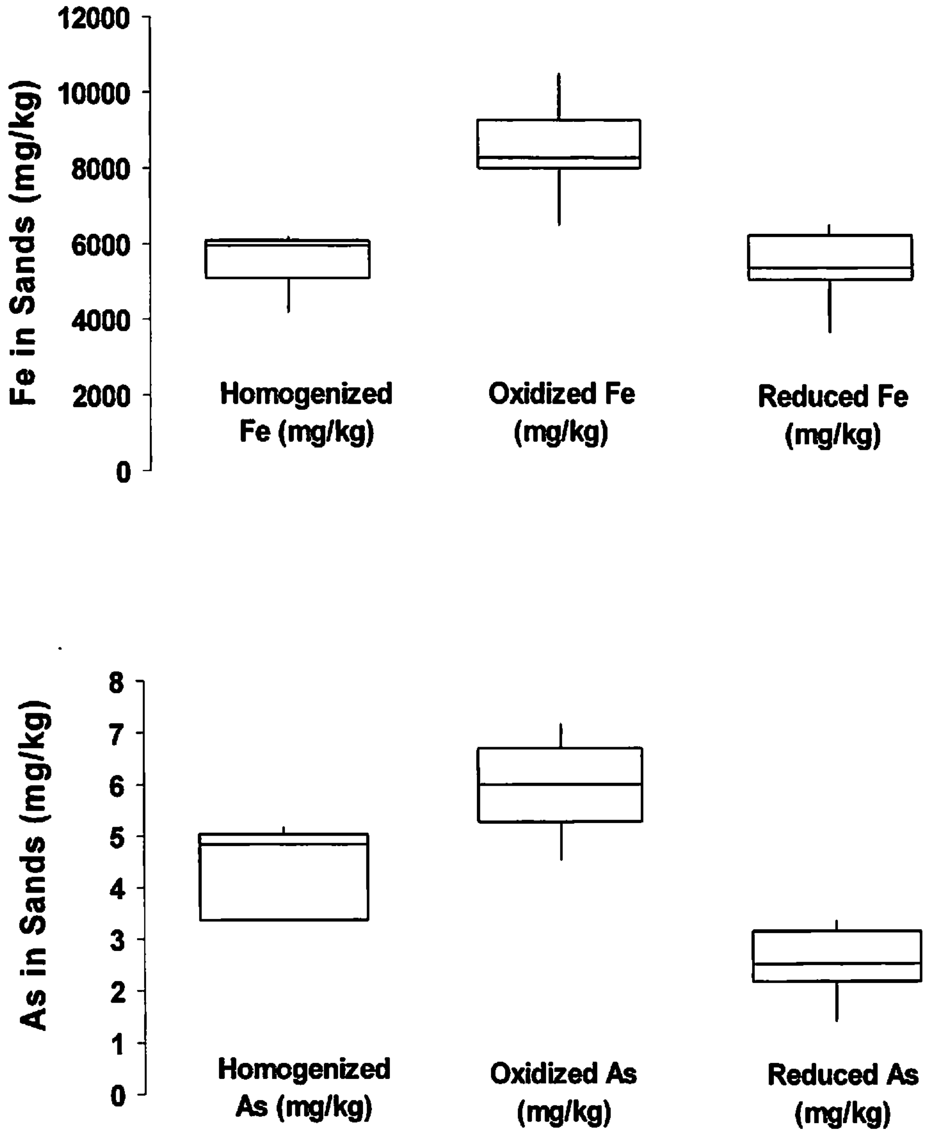
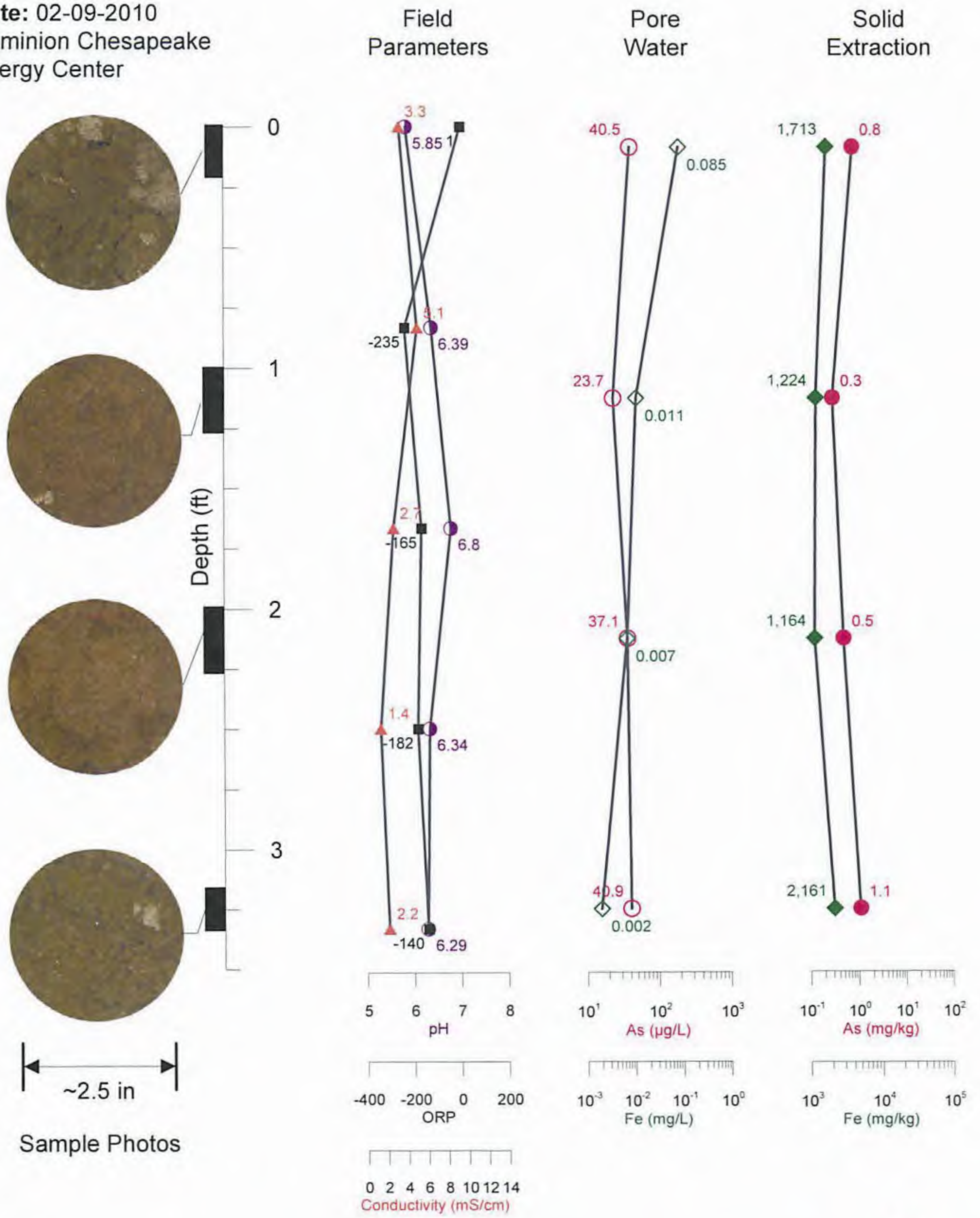


Figure 4-2. Box plots of arsenic and iron concentrations in sands for homogenized samples as compared to color-classified ‘oxidized’ and ‘reduced’ portions of the core sample.

Core: 1A
Date: 02-09-2010
Dominion Chesapeake
Energy Center



Legend

- ◐ Field pH
- ■ Field ORP
- ▲ Field Conductivity
- ○ Dissolved Phase Arsenic
- ◇ Dissolved Phase Iron
- ● Soild Phase Arsenic
- ◆ Soild Phase Iron

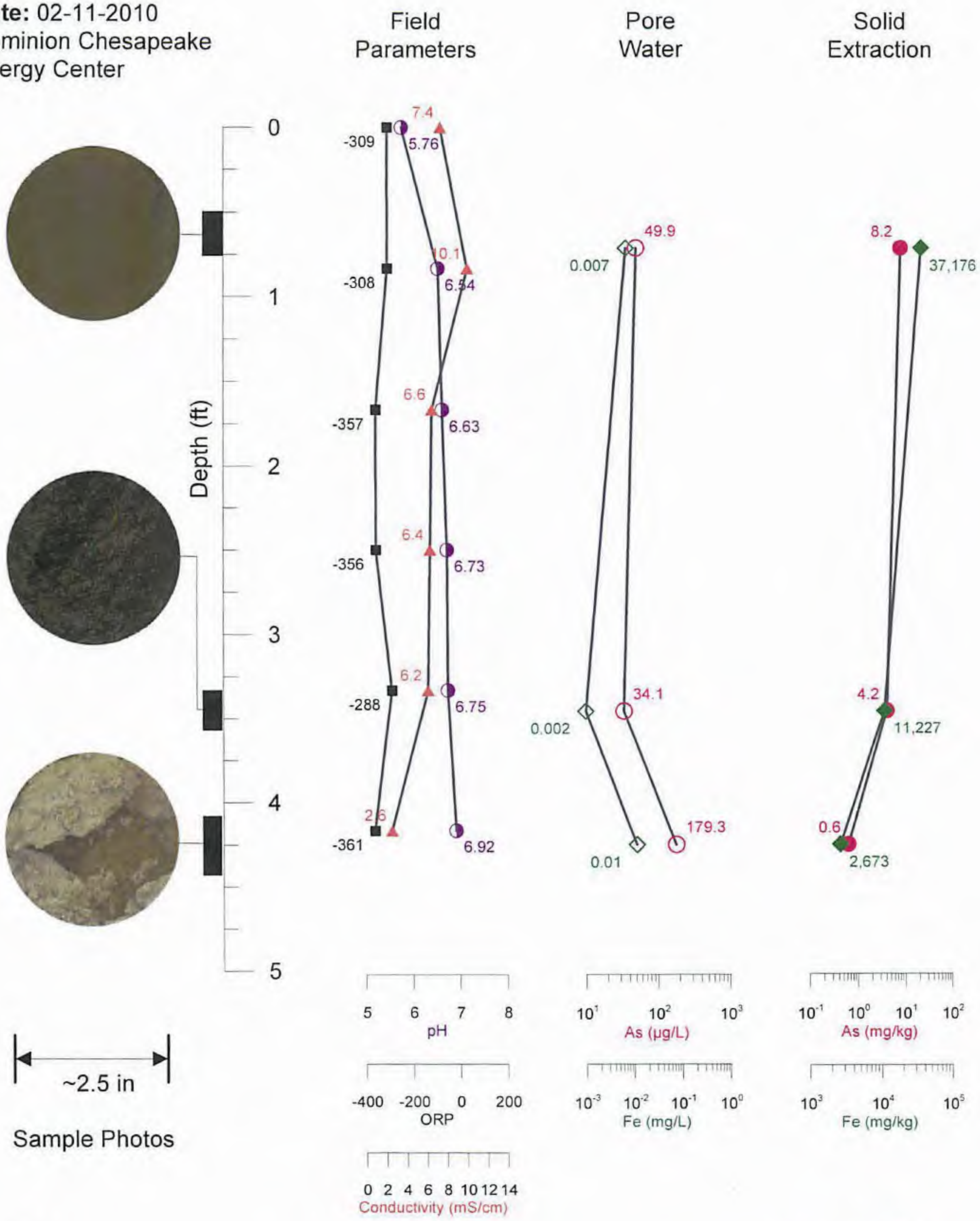
Notes:

The detection limit for dissolved phase iron is 0.002 mg/L. This value was used for non-detect concentration of dissolved iron at the deepest sampling interval.

amec
8519 Jeffereson Ave
Albuquerque, NM 87113
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-3

Core: 1B
Date: 02-11-2010
Dominion Chesapeake
Energy Center



Legend

- ◐ Field pH
- ■ Field ORP
- ▲ Field Conductivity
- ○ Dissolved Phase Arsenic
- ◇ Dissolved Phase Iron
- ● Soild Phase Arsenic
- ◆ Soild Phase Iron

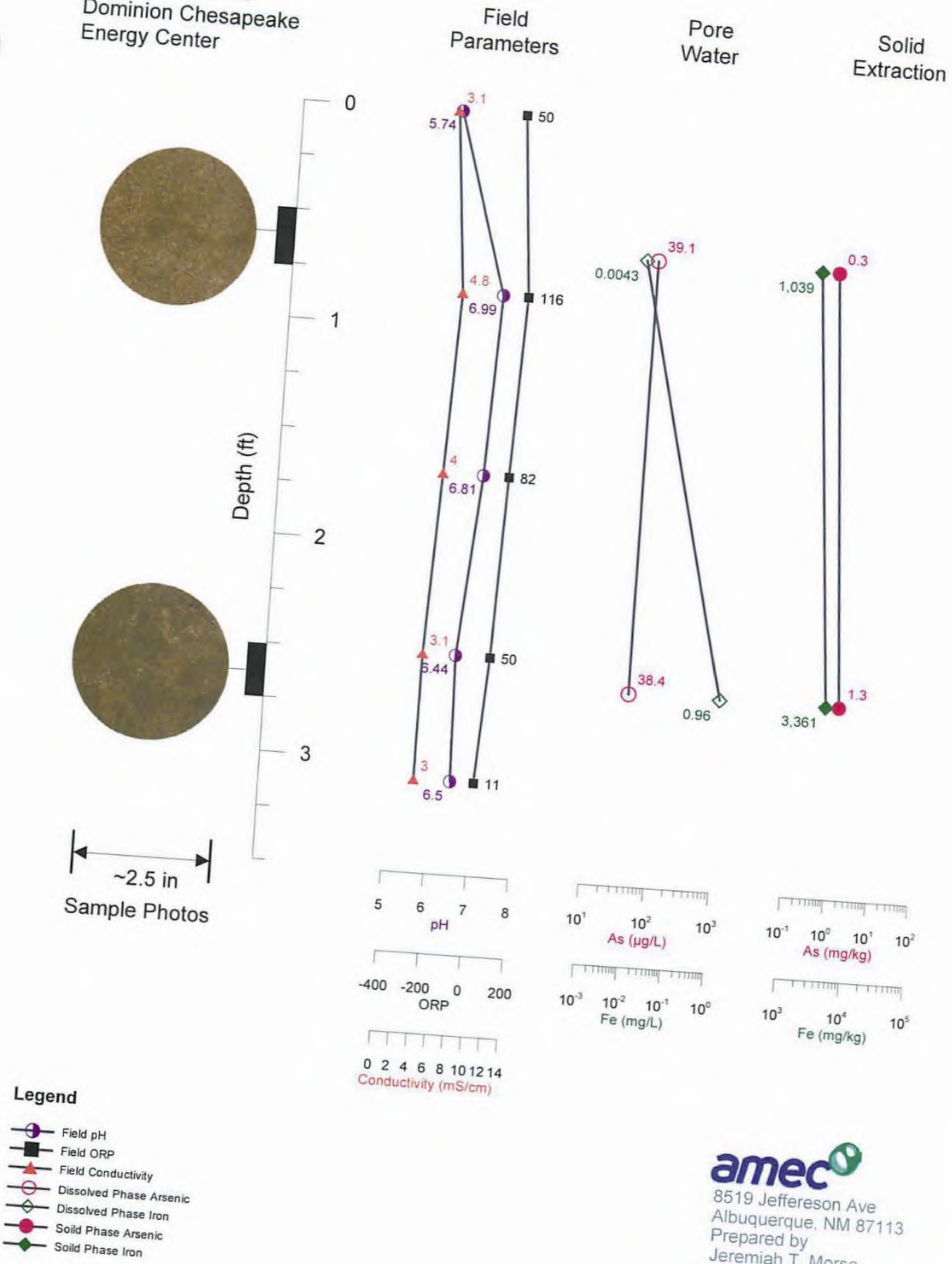
Notes:

The detection limit for dissolved phase iron is 0.002 mg/L. This value was used for non-detect concentration of dissolved iron at the second deepest sampling interval.

amec
8519 Jeffereson Ave
Albuquerque, NM 87113
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-4

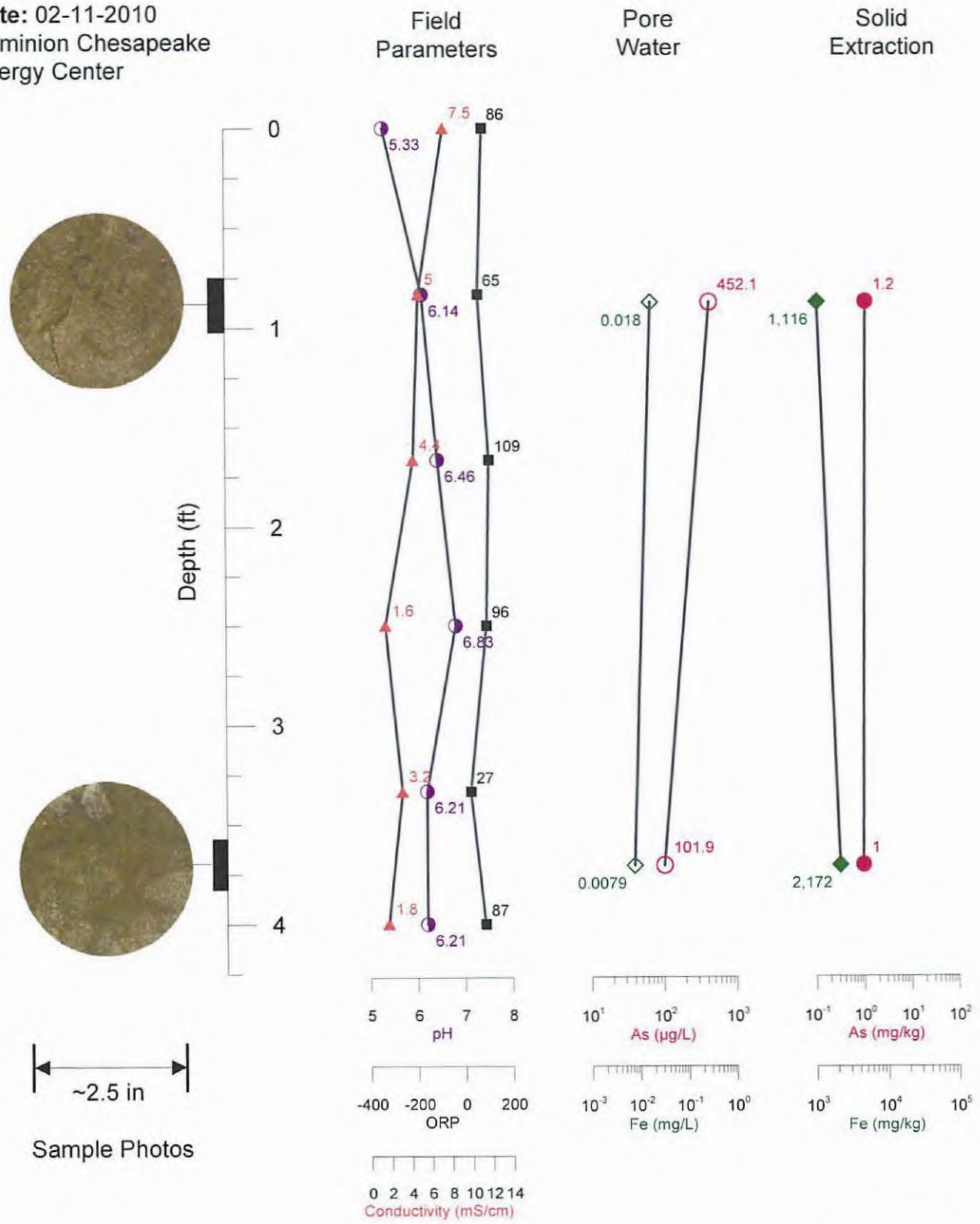
Core: 1C
Date: 02-11-2010
Domion Chesapeake
Energy Center



amec
8519 Jeffereson Ave
Albuquerque, NM 87113
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-5

Core: 2A
Date: 02-11-2010
Dominion Chesapeake
Energy Center



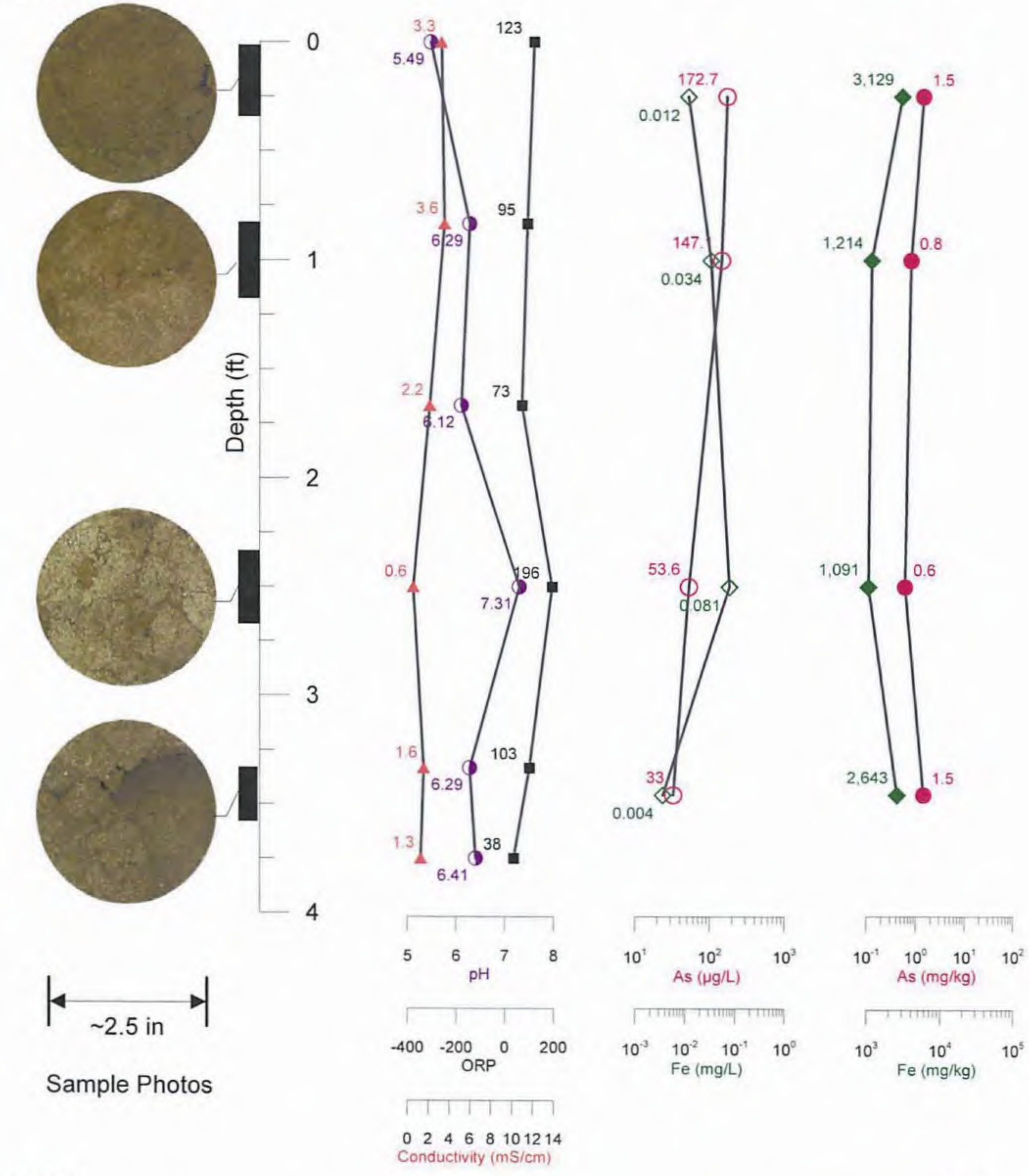
Legend

- ◐ Field pH
- ■ Field ORP
- ▲ Field Conductivity
- ○ Dissolved Phase Arsenic
- ◇ Dissolved Phase Iron
- ● Soild Phase Arsenic
- ◆ Soild Phase Iron

amec
8519 Jefferson Ave
Albuquerque, NM 87113
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-6

Core: 2B
Date: 02-11-2010
Dominion Chesapeake
Energy Center



Legend

- ◐ Field pH
- ■ Field ORP
- ▲ Field Conductivity
- ○ Dissolved Phase Arsenic
- ◇ Dissolved Phase Iron
- ● Soild Phase Arsenic
- ◆ Soild Phase Iron

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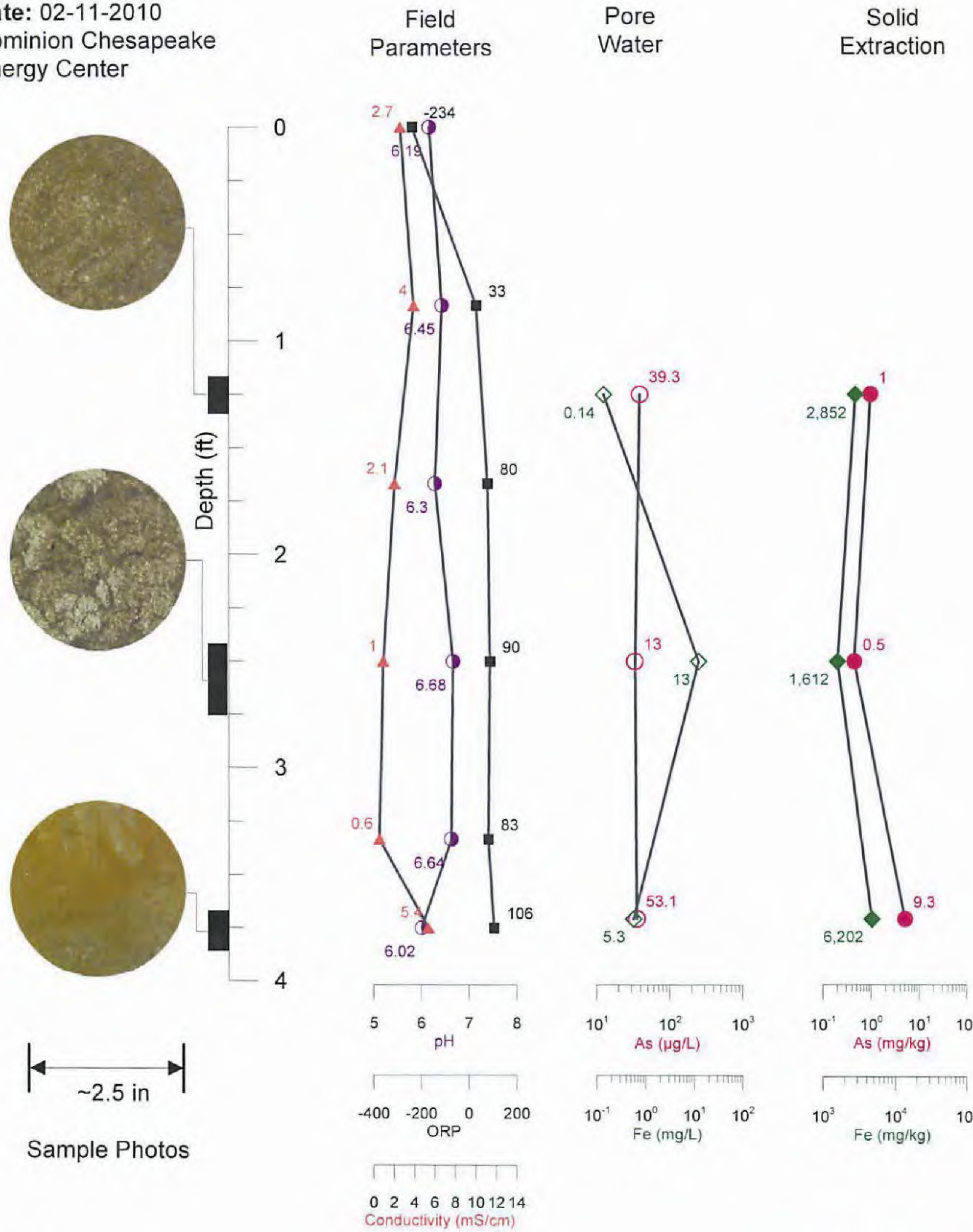
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-7

Core: 2C
Date: 02-11-2010
Dominion Chesapeake
Energy Center



Legend

- Field pH
- Field ORP
- Field Conductivity
- Dissolved Phase Arsenic
- Dissolved Phase Iron
- Soild Phase Arsenic
- Soild Phase Iron

amec
8519 Jefferson Ave
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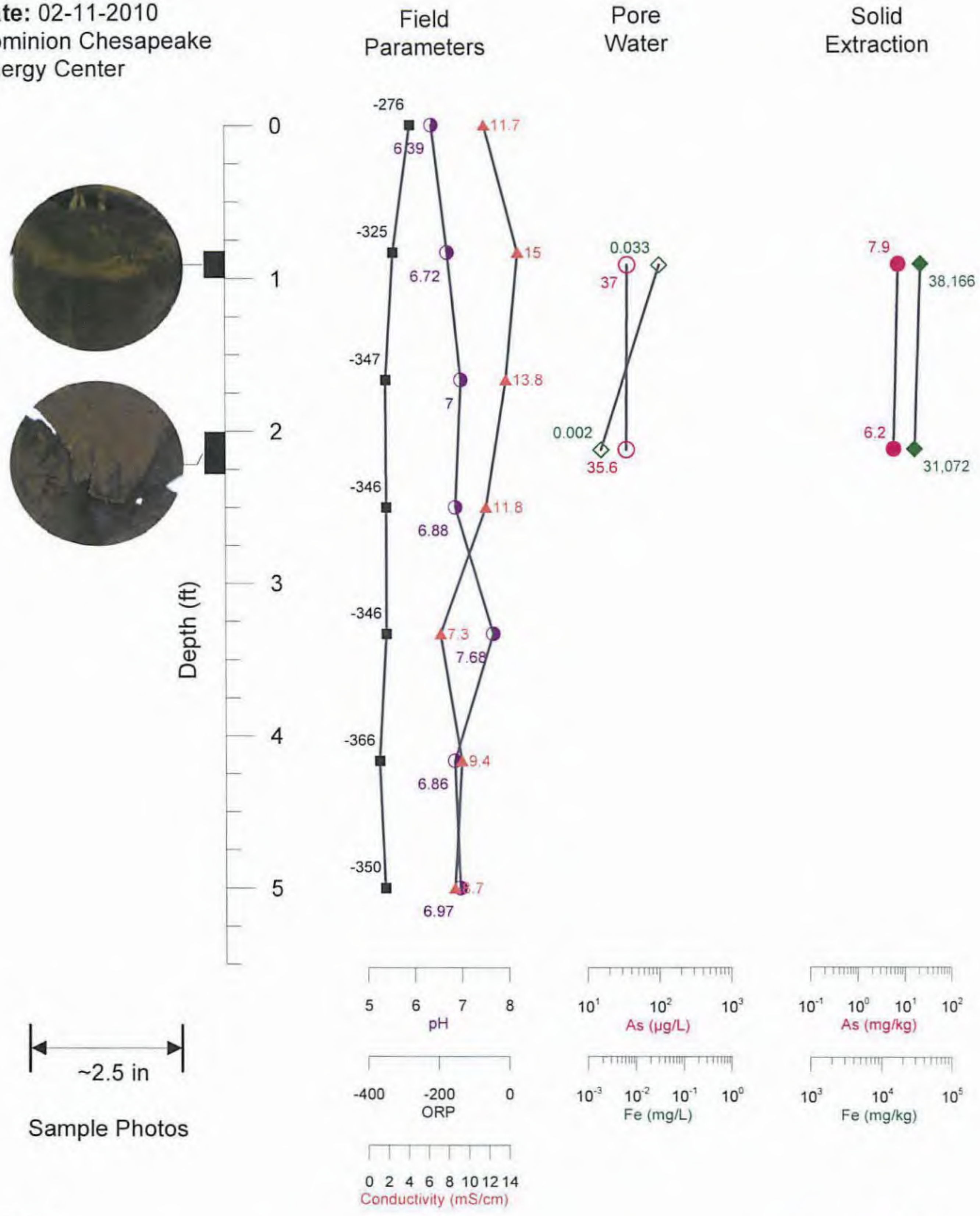
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-8

Core: 3C
Date: 02-11-2010
Dominion Chesapeake
Energy Center



Legend

- ◐ Field pH
- ■ Field ORP
- ▲ Field Conductivity
- ○ Dissolved Phase Arsenic
- ◇ Dissolved Phase Iron
- ● Soild Phase Arsenic
- ◆ Soild Phase Iron

Notes:

The detection limit for dissolved phase iron is 0.002 mg/L. This value was used for non-detect concentration of dissolved iron at the deepest sampling interval.

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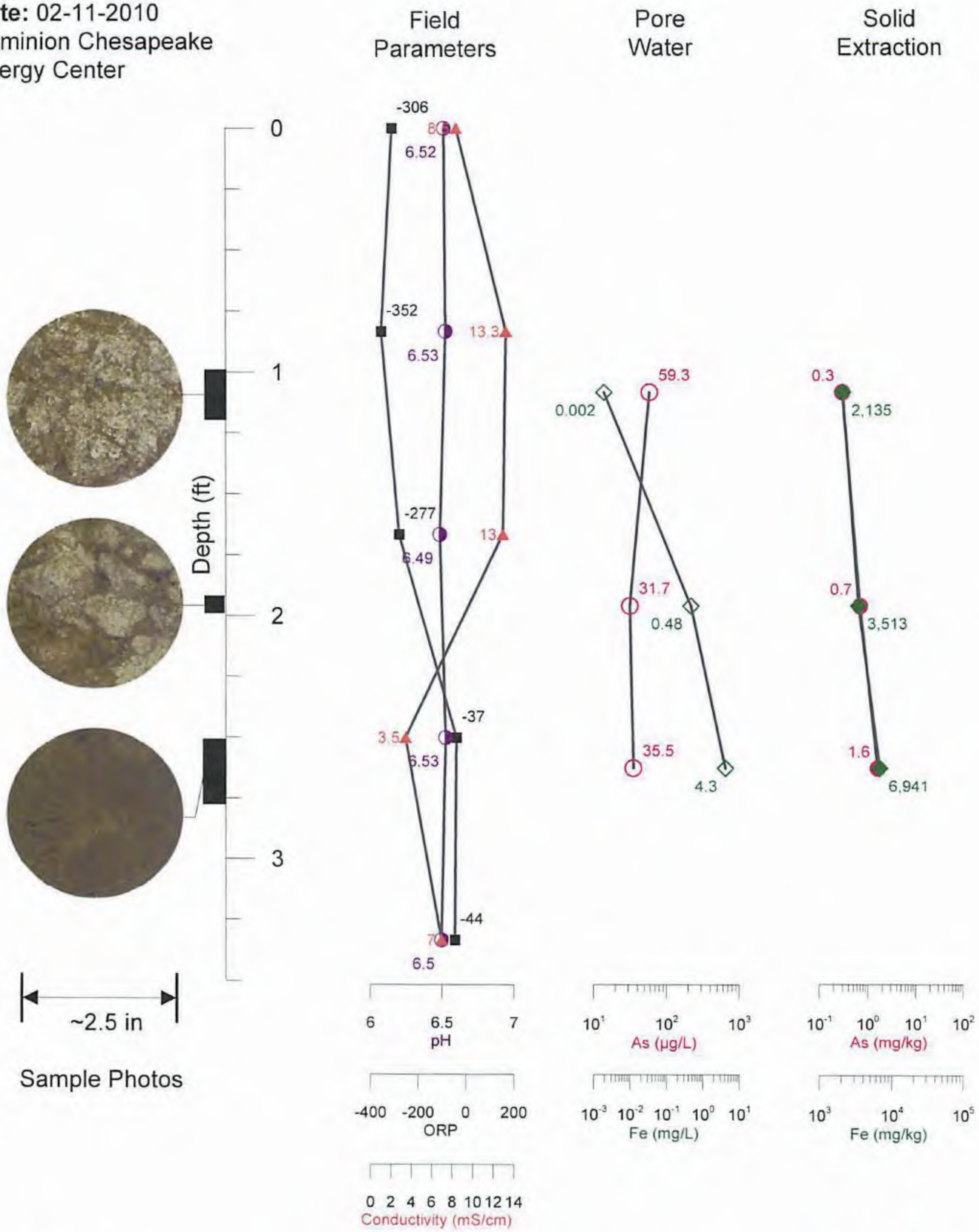
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-9

Core: 4A
Date: 02-11-2010
Dominion Chesapeake
Energy Center



Legend

- Field pH
- Field ORP
- Field Conductivity
- Dissolved Phase Arsenic
- Dissolved Phase Iron
- Solid Phase Arsenic
- Solid Phase Iron

Notes:

The detection limit for dissolved phase iron is 0.002 mg/L. This value was used for non-detect concentration of dissolved iron at the shallowest sampling interval.

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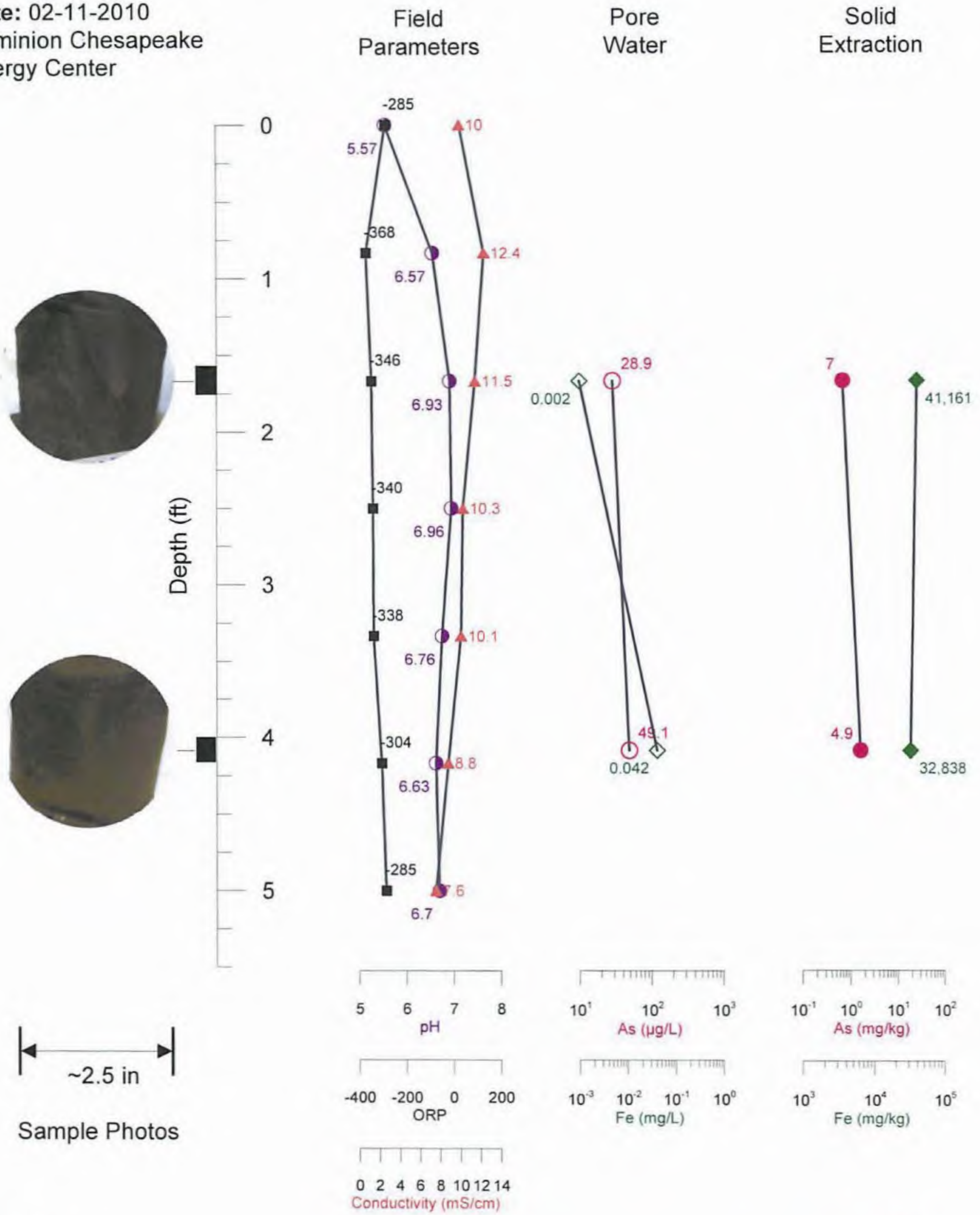
Jeremiah T. Morse
March 15, 2010

Figure 4-10

Core: 4B
Date: 02-11-2010
Dominion Chesapeake
Energy Center



Legend

- ◐ Field pH
- ■ Field ORP
- ▲ Field Conductivity
- ○ Dissolved Phase Arsenic
- ◇ Dissolved Phase Iron
- ● Soild Phase Arsenic
- ◆ Soild Phase Iron

Notes:

The detection limit for dissolved phase iron is 0.002 mg/L. This value was used for non-detect concentration of dissolved iron at the shalowest sampling interval.

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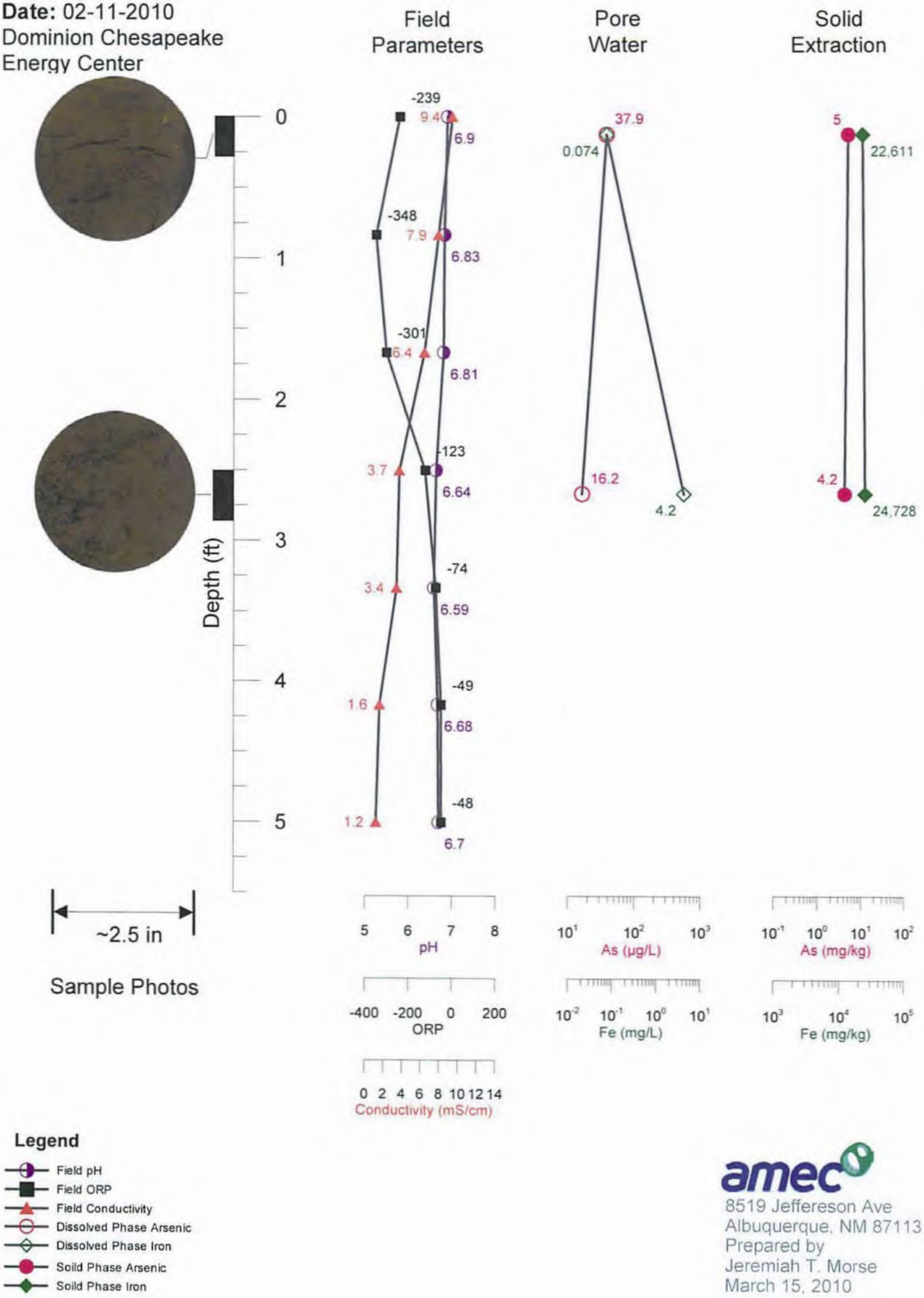
Jeremiah T. Morse
March 15, 2010

Figure 4-11

Core: 4C
Date: 02-11-2010
Dominion Chesapeake
Energy Center



amec
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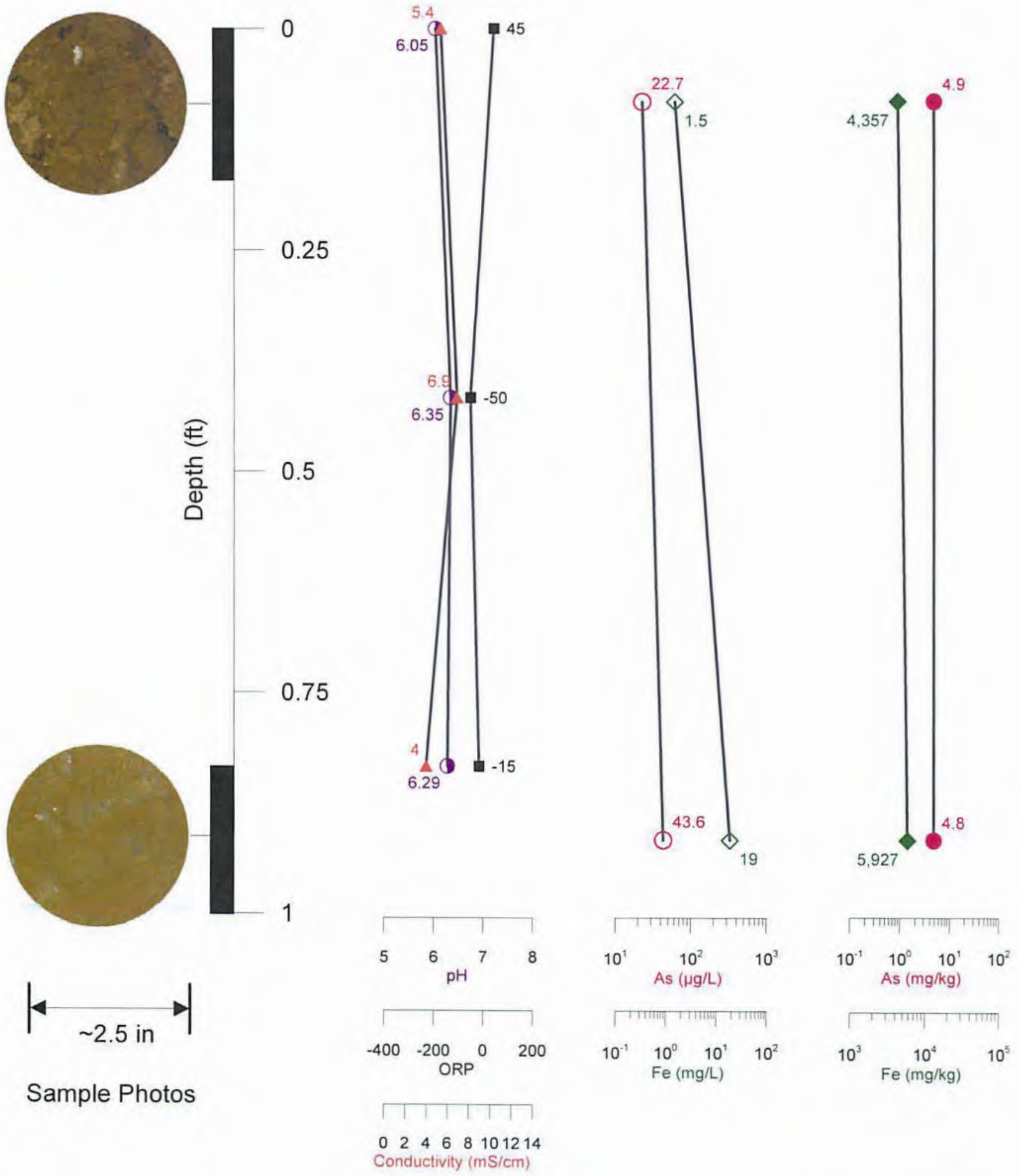
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-12

Core: 6A
Date: 02-09-2010
Dominion Chesapeake
Energy Center



Legend
- ◑ Field pH
- ■ Field ORP
- ▲ Field Conductivity
- ○ Dissolved Phase Arsenic
- ◇ Dissolved Phase Iron
- ● Soild Phase Arsenic
- ◆ Soild Phase Iron

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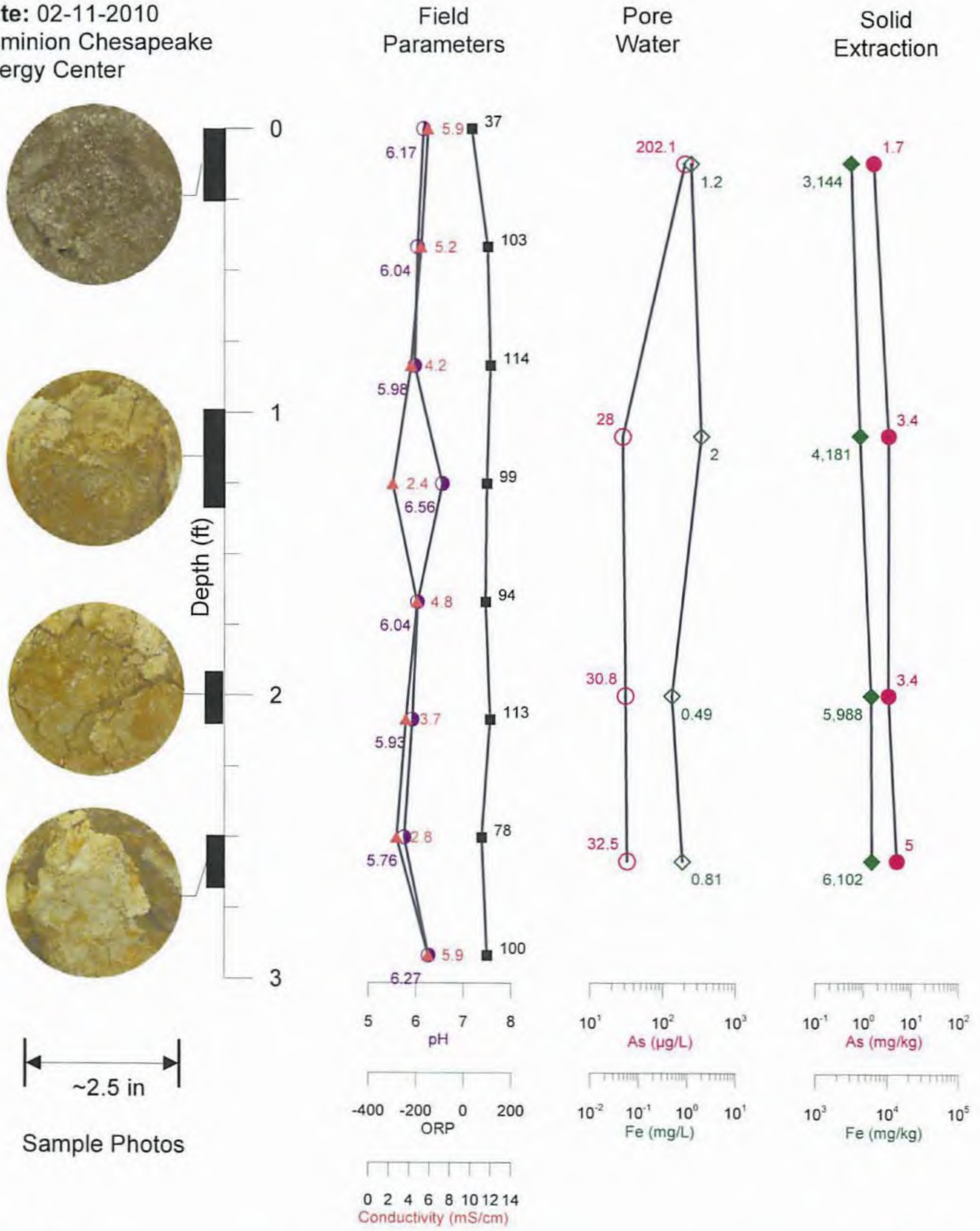
Albuquerque, NM 87113
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-13

Core: 6B
Date: 02-11-2010
Dominion Chesapeake
Energy Center



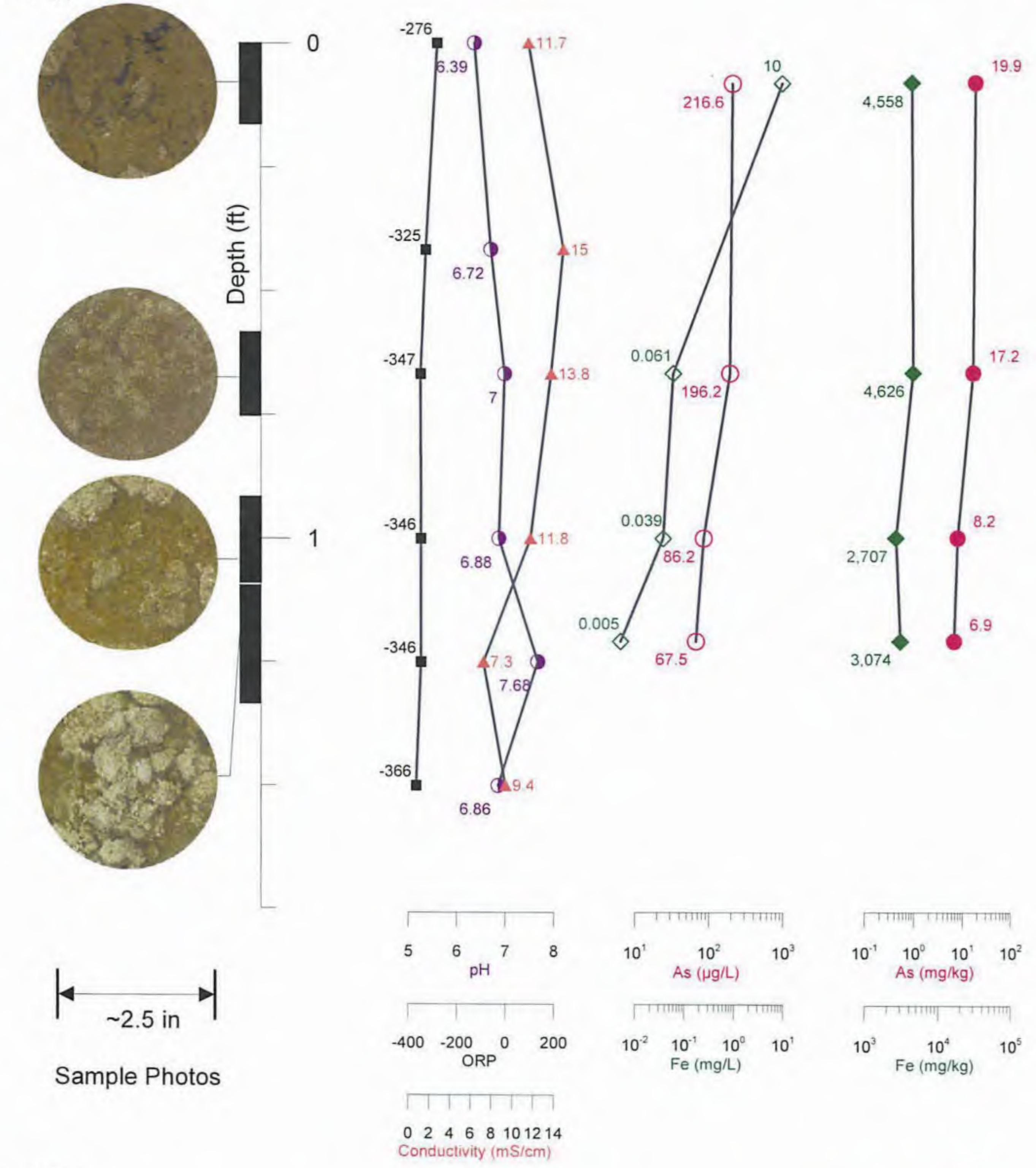
Legend

- Field pH
- Field ORP
- Field Conductivity
- Dissolved Phase Arsenic
- Dissolved Phase Iron
- Soild Phase Arsenic
- Soild Phase Iron

amec
8519 Jefferson Ave
Albuquerque, NM 87113
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-14

Core: 7A
Date: 02-11-2010
Dominion Chesapeake
Energy Center



Legend

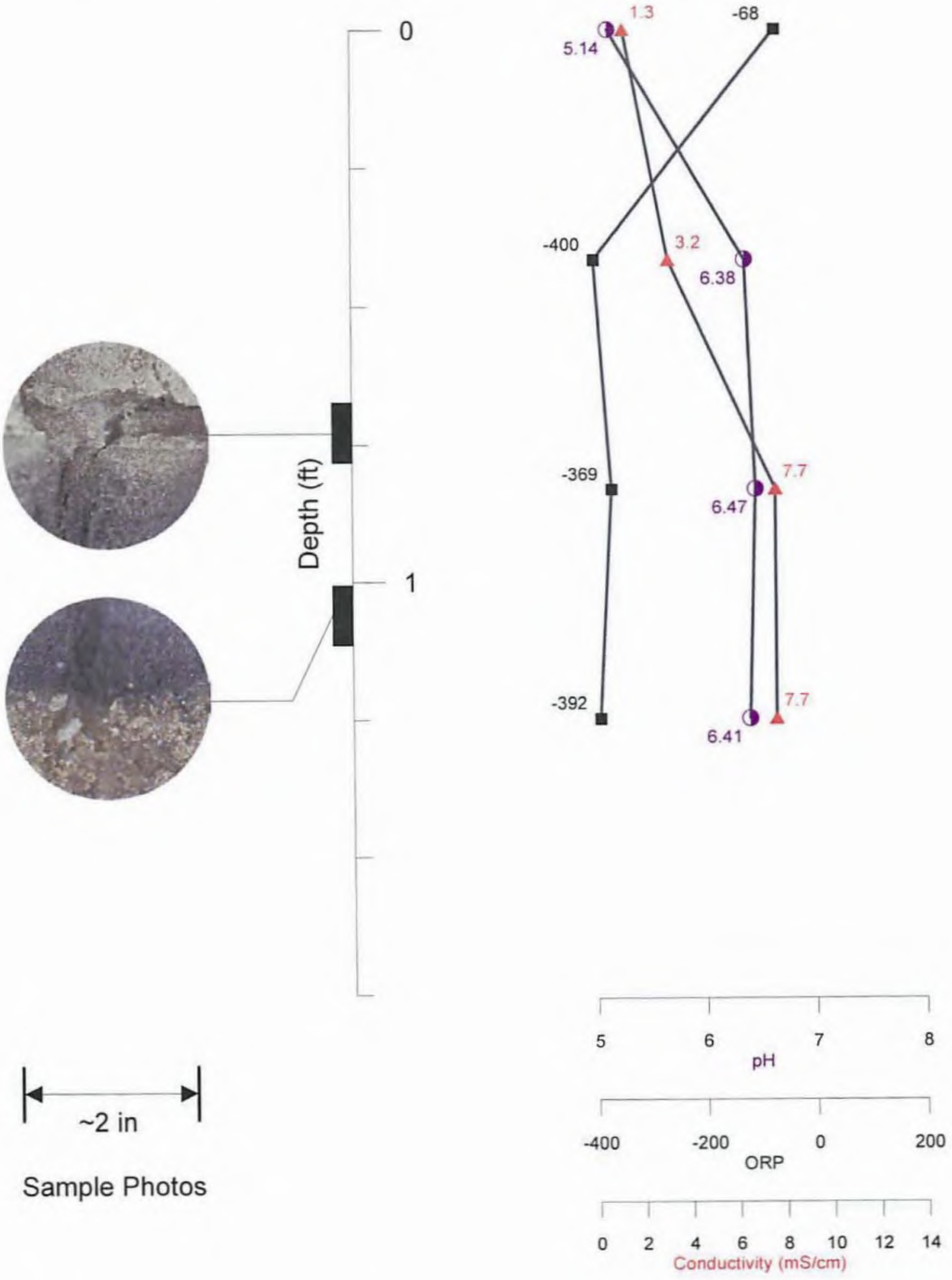
- ◐ Field pH
- ■ Field ORP
- ▲ Field Conductivity
- ○ Dissolved Phase Arsenic
- ◇ Dissolved Phase Iron
- ● Soild Phase Arsenic
- ◆ Soild Phase Iron

amec
8519 Jeffereson Ave
Albuquerque, NM 87113
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-15

Core: Test 5A
Date: 02-09-2010
Dominion Chesapeake Energy Center

Field Parameters



Legend

- ◐ Field pH
- ■ Field ORP
- ▲ Field Conductivity

Notes:

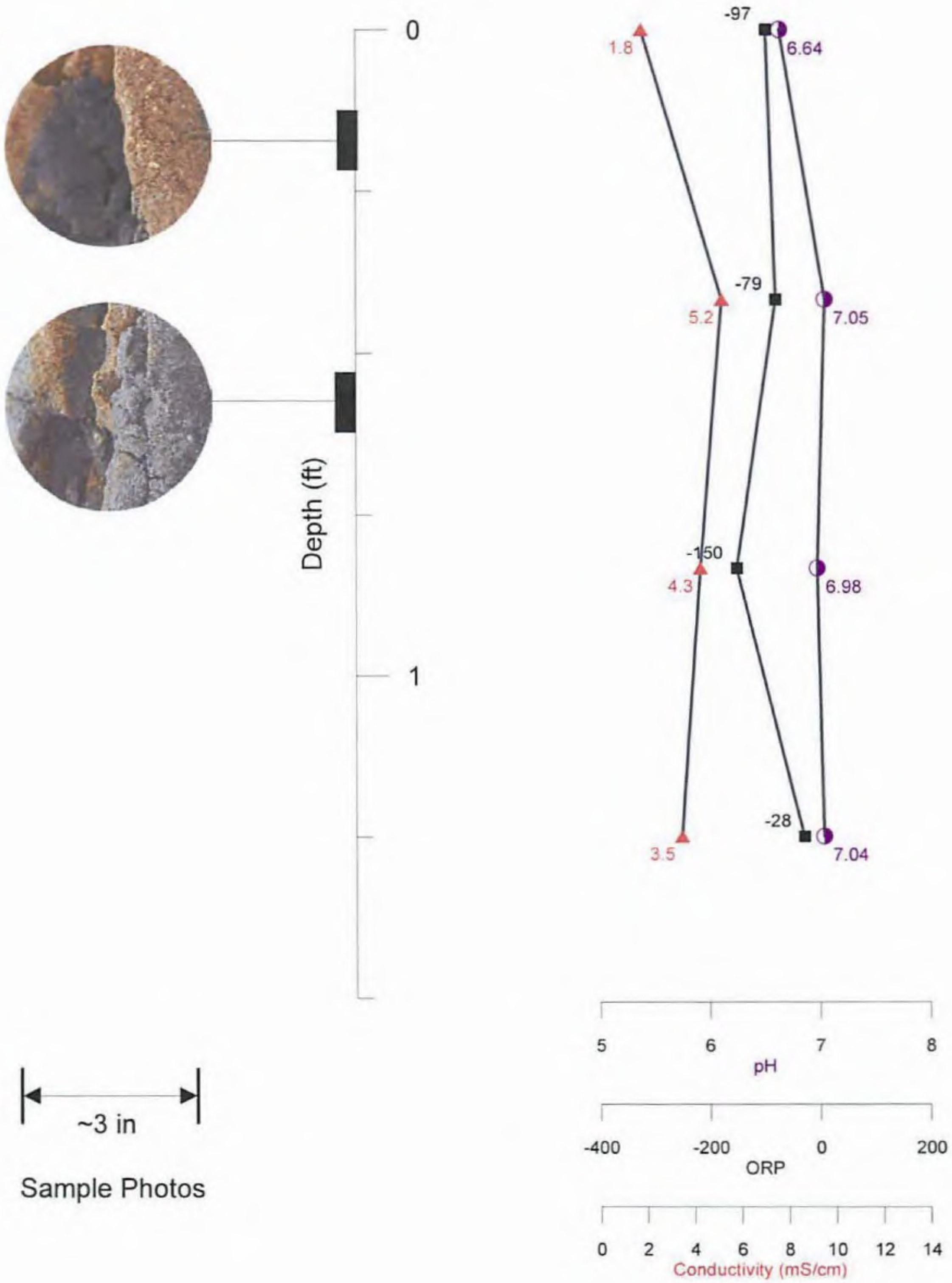
Only field parameters and pictures were documented. No samples were taken from this core.

amec
8519 Jeffereson Ave
Albuquerque, NM 87113
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-16

Core: Test 5B
Date: 02-09-2010
Dominion Chesapeake Energy Center

Field
Parameters



Legend

- Field pH
- Field ORP
- Field Conductivity

Notes:
Only field parameters and pictures were documented. No samples were taken from this core.

amec
8519 Jeffereson Ave
Albuquerque, NM 87113
Prepared by
Jeremiah T. Morse
March 15, 2010

Figure 4-17

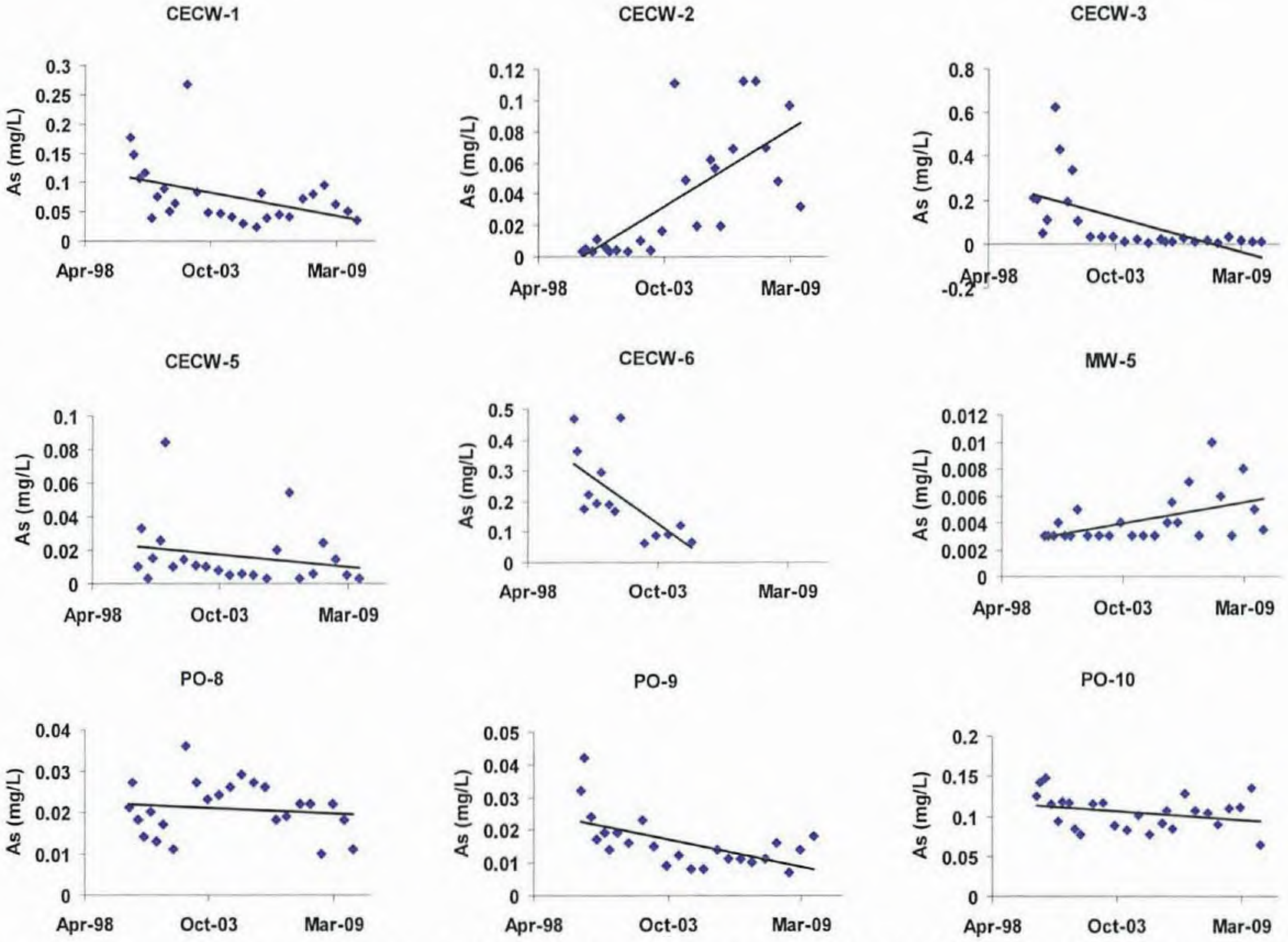


Figure 4-18. Trends in arsenic concentration over time for nine wells at the CEC landfill. Most wells at the landfill have had arsenic levels decline over time.

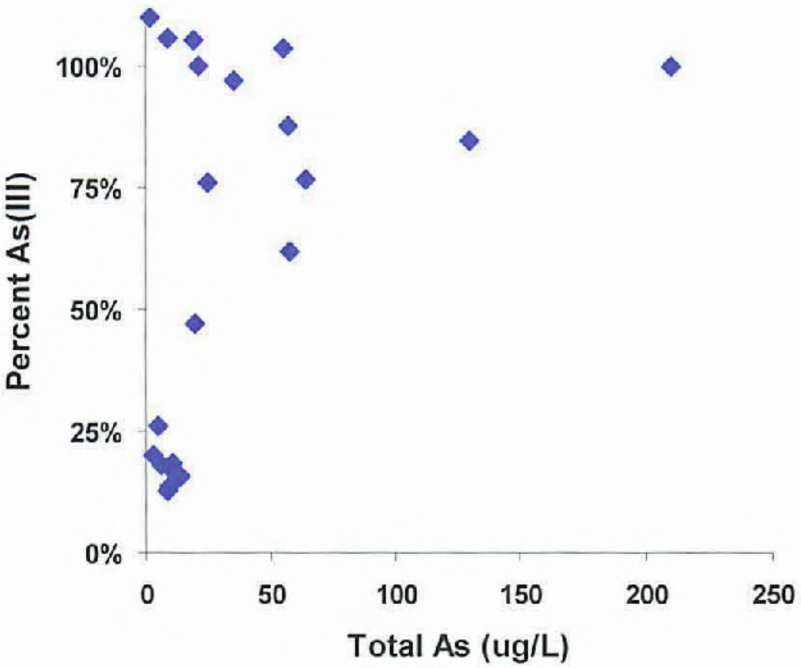
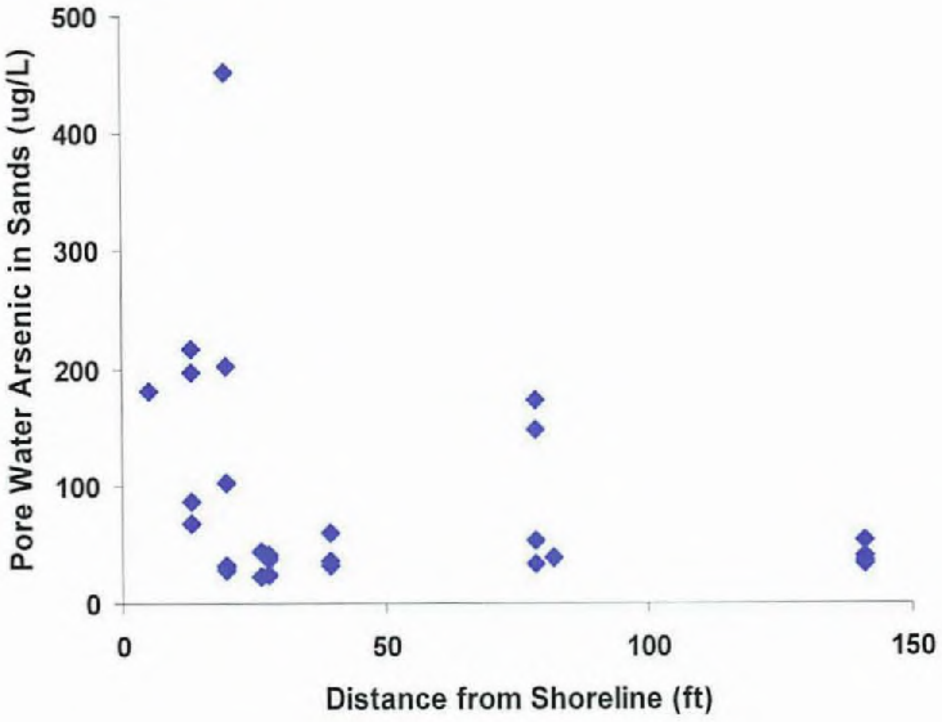


Figure 4-19. As(III) percentage as compared to total arsenic concentration shows a weak correlation. Higher total arsenic values trend towards 100% As(III) speciation.



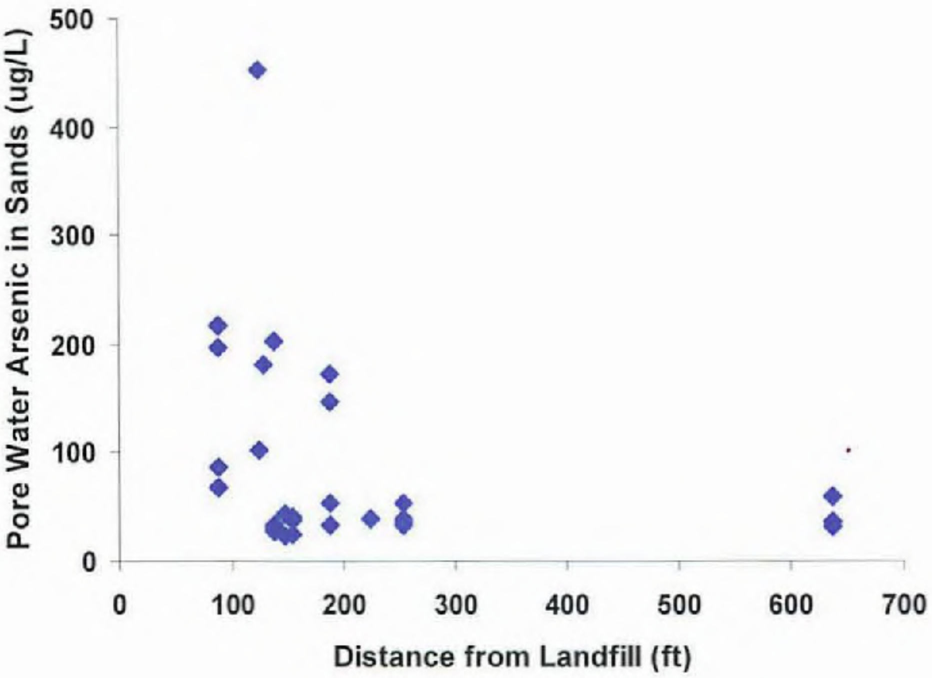


Figure 5-1. Pore water arsenic concentrations trend downward with distance from the landfill and/or shoreline.

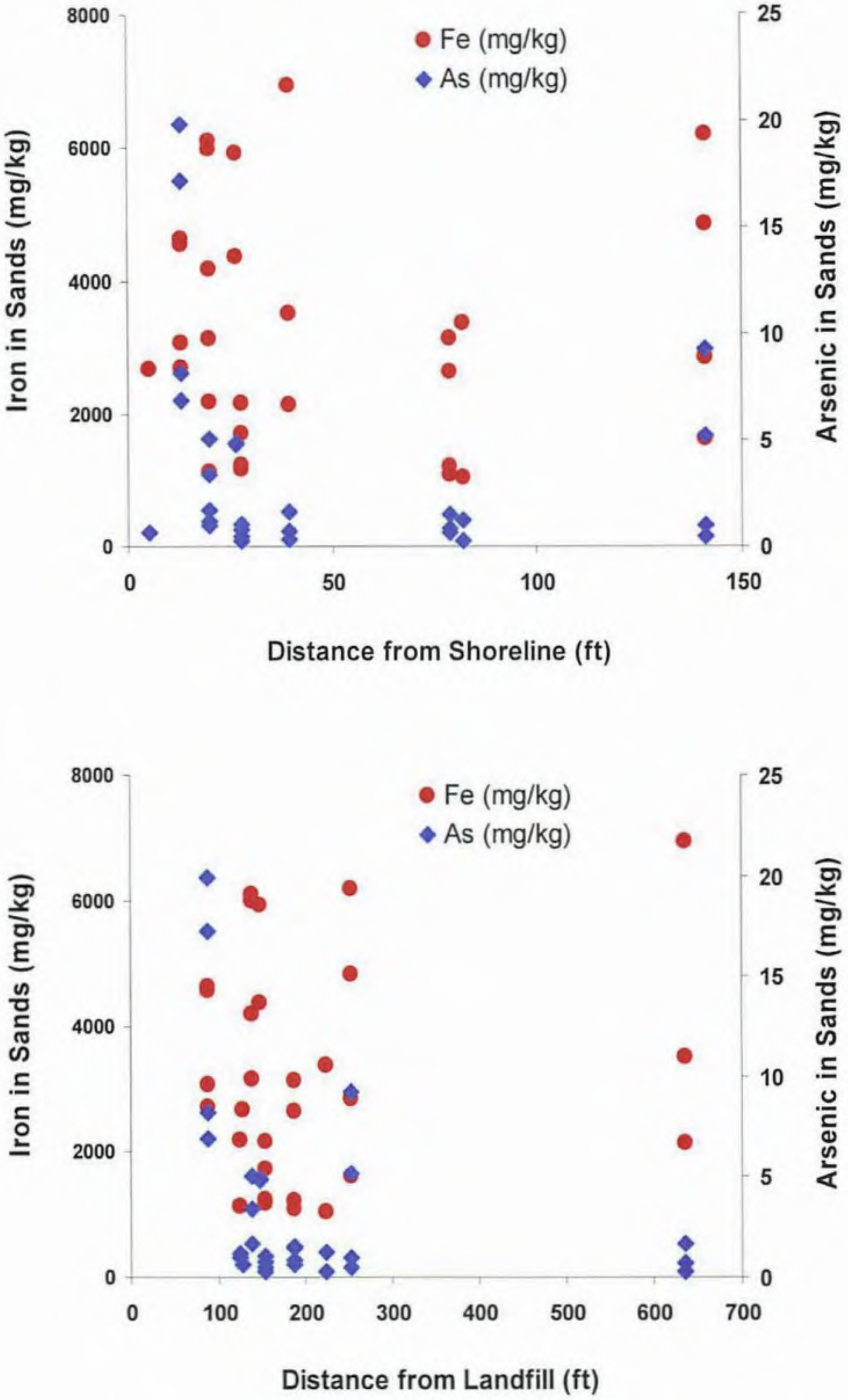


Figure 5-2. **Arsenic and iron concentrations in nitric acid extractions of Norfolk Formation sands trend downward with distance from the landfill.**

APPENDIX A

MACTEC RISK ASSESSMENT - 2003

RISK ASSESSMENT FOR CHESAPEAKE ENERGY CENTER

Prepared for:

Dominion Generation
Environmental Policy and Compliance
5000 Dominion Boulevard
Glen Allen, VA 23060

PROJECT NO: 3530-03-1266

December 26, 2003

MACTEC

TABLE OF CONTENTS

1. Introduction

The Chesapeake Energy Center (CEC) Industrial Landfill (landfill) is located in Chesapeake, Virginia. As a result of an exceedence of the groundwater protection standard (GPS) for arsenic and sulfide within the landfill's compliance groundwater monitoring program, an Assessment of Corrective Measures (ACM) in compliance with solid waste regulations of the Virginia Department of Environmental Quality (DEQ) has been required. The Assessment of Corrective Measures addresses, in a phased manner, the nature and extent of the potential impact to groundwater and identifies and assess potential corrective measures that may be necessary.

As part of this report, a risk assessment has been conducted consistent with the guidelines of the Virginia Voluntary Remediation Regulations (Section 9 VAC 20-160-70 (A)(1)(a) of Virginia Administrative Code), which includes an evaluation of the risks to human health and the environment posed by the environmental conditions at the landfill. To that end, this report includes the risk assessment for groundwater associated with the landfill area and soil from the portion of the landfill that may be frequented by non-Dominion employees.

1.1. Site History

CEC occupies approximately 145 acres of property, approximately 8 miles west of Virginia Beach and 7 miles south of the City of Norfolk. The eastern boundary is the Southern Branch of the Elizabeth River (SBER), the southern boundary is Deep Creek, and the western boundary a cooling water discharge canal to Deep Creek. CEC is a 628 megawatt, coal-fired, electric generation facility that began operations in the early 1950's and has always been owned and operated by Dominion.

Data from the 1960s and 1970s indicate as many as three settling basins for coal ash were constructed on a peninsula that is located along the southern portion of the CEC property. In 1985 the existing landfill was constructed over the sedimentation basins (DEQ Solid Waste Permit No. 440).

CEC currently utilizes the landfill for the disposal of coal ash, or coal combustion by-products. The landfill is used exclusively for the disposal of coal combustion by-products generated by CEC. The footprint consists of approximately 22.25 acres and is lined with a 20–mil high density polyethylene (HDPE) flexible geomembrane liner.

Groundwater at the landfill is monitored by CEC to assess any changes of its quality. Groundwater monitoring has been conducted since 1984. Arsenic concentrations were reported in the uppermost (shallow) aquifer underlying the landfill at concentrations that statistically exceed the groundwater protection standard (GPS) of 50 micrograms per liter (ug/L) during 2002. The range of arsenic concentrations in monitoring wells that exceeded the standard is generally between 50 and 350 ug/L.

In addition to arsenic, the September 2002 groundwater monitoring event indicated GPS exceedances for sulfides in one background and two downgradient wells, MW4, CECW4 and PO8, respectively. Also the March 2003 sampling event identified a GPS exceedance of sulfide in one well, CECW2. While this may be related to background conditions, nonetheless, sulfides have been included as a Constituent of Potential Concern (COPC) in this assessment as part of the landfill's corrective action program.

1.2. Hydrogeologic Setting

The landfill is located in the Atlantic Coastal Plain physiographic province on an inverted L-shaped peninsula. The peninsula is surrounded by the SBER, Deep Creek and a noncontact cooling water discharge channel. Prior to development, the peninsula was underdeveloped and consisted of tidal channels and low-laying grass and wooded areas. Tidal marsh presently exists on the peninsula, to the south of the landfill.

The upper most stratum beneath the landfill is vertically and horizontally variable and consists of construction fill (that may contain ash), buried bottom and fly ash from historic sedimentation basins and alluvial deposits from Deep Creek and the SBER (URS, 2003). Groundwater flow velocity within the fill material ranges from 1.5-to 5.0 feet/year. Below the upper most strata, the local geology consist of variable layer of silty sand to sand, representing the Norfolk formation, atop the Yorktown confining unit. Groundwater velocities in the sediments at the site range from 287 to 323 feet/year with velocities decreasing with depth toward the east and is believed to discharge to the SBER and cooling water channel along preferential flow paths within the Norfolk formation.

Tides have a variable influence on hydraulic conditions beneath the landfill. Additionally, there appears to be a downward vertical gradient from the upper to the lower portion of the aquifer (URS, 2003). Groundwater emanating from the landfill area likely moves toward the tidal marsh area and subsequently upward flow to the South Branch of the Elizabeth River and Deep Creek.

1.3. Water Supply and Resources

No public or private water supply wells are known to lie within 1,000 feet of the landfill (URS, 2003, EDR, 2002). The station and structures in the vicinity obtain drinking water from public water supply lines. Groundwater is not used as a drinking water source in the vicinity.

1.4. Regional Setting

The landfill is located within the heavily urbanized Elizabeth River watershed, a tributary of Chesapeake Bay. Impacts from residential communities, as well as industrial, commercial and federal government military facilities have lead to the watershed being named as a Region of Concern and an EPA Pilot River Project (ERP, 2003). The SBER is listed as a severe problem for all measurement factors except dissolved metals. The SBER currently rates as a "severe problem" for PAHs in sediment, Benthic Community Health, Mummichog cancer, Dissolved Oxygen and TBT. The SBER rates as "no problem" for metals. Copper was noted as the only metal at elevated levels in the SBER, however, the levels did not exceed criterion(Elizabeth River Project, 2003).

The Elizabeth River is one of approximately 150 major rivers and streams in the Chesapeake Bay drainage system and is noted as being severely impacted (URS, 2003). The Elizabeth River is approximately 20 miles long with drainage area that encompasses approximately 300 square miles within Atlantic Coastal Plan Physiographic Providence including major portions of Dismal Swamp. In addition, numerous streams and rivers flow into the Elizabeth River, including the Lafayette River and Deep Creek.

Industrial use of the Elizabeth River started in the early 1600's resulting in possible spills and discharges of wastes into the river and associated sediment (URS, 2003). Three creosote wood preserving facilities have historically been located on the SBER, north of CEC, two of which were in operation prior to 1900. Known contaminants associated with these facilities include polycyclic aromatic hydrocarbons (PAHs) and metals including arsenic and chromium.

The shipbuilding industry that was and is currently present on the SBER has been associated with discharges of metals and organics. (URS, 2003) In addition, in the 1940's and 1950's, the SBER was the site of numerous fertilizer plants that have been linked to discharges of contaminants such as chromium, zinc and excess nitrogen and phosphorous. The petroleum industry also has a presence on the SBER and has been associated with organic and inorganic discharges.

1.5. Terrestrial Habitats

The cover types associated with the landfill are primarily upland, although a small area of tidal marsh dominates the southern tip of the peninsula (URS, 2003). Descriptions of the ecological resources associated with these areas are presented in the ACM. The terrestrial areas are considered as two types that include the surface of the landfill and the vegetated shoreline slope down to the SBER, Deep Creek and the Cooling Water Channel.

2. Data Collection and Evaluation

Five surface water samples were collected on December 2, 2003 adjacent to the landfill on Deep Creek and the Southern Branch of the Elizabeth River. Four background (upstream) surface water samples were collected in the northern and southern branches of Deep Creek and the Southern Branch of the Elizabeth River. A total of nine surface water samples were collected at low tide and at a depth of one foot below the surface at the following locations:

Sample Identification	Sample Location	Sample Time
# 1 - Southern Branch of Deep Creek - Upstream of the landfill	N 36° 45.465' W 76° 18.485'	12/2/03 11:15
#2 - Deep Creek at Discharge into Southern Branch of Elizabeth River	N 36° 45.436' W 76° 18.064'	12/02/03 11:20
#3 – Upstream - Southern Branch of Elizabeth River – West Side	N 36° 45.244' W 76° 17.756'	12/02/03 11:35
#4 – Upstream Southern Branch of Elizabeth River – East Side	N 36° 45.238' W 76° 17.592'	12/02/03 11:40
#5 - CEC Cooling Water Canal at discharge to Deep Creek	N 36° 45.711' W 76° 18.320'	12/02/03 11:48
#6 – Northern Branch of Deep Creek Upstream of CEC cooling water discharge	N 36° 45.686' W 76° 18.413'	12/02/03 11:55
#7 – Northern Channel of Deep Creek before discharge to Elizabeth River	N 36° 45.557' W 76° 18.079'	12/02/03 12:10
#8 – Southern Branch of Elizabeth River Downstream of the landfill	N 36° 46.039' W 76° 17.956'	12/02/03 12:20
#9 – Southern Branch of Elizabeth River Downstream of the landfill	N 36° 46.102' W 76° 17.791'	12/02/03 12:25

A map indicating the location of the sampling points is shown in Figure 2.

The design of the sampling device prevented cross contamination of the samples. A new one liter glass bottle was attached to the sampling device for each sample collected. After the sampling device was lowered into the stream to a depth of one foot, the container cap was removed to allow sample to flow into the bottle. After the bottle was completely filled, the sampling device was maintained at the sampling depth and the bottle cap was replaced before the sample was retrieved.

After each sampling point, a new bottle and cap were installed for the next sampling event. Samples were immediately placed in a cooler and transported to the marina for splitting into the various fractions.

A 250 ml fraction of the sample for total arsenic analysis was placed in pre-cleaned 250 ml plastic bottle and preserved with HNO_3. An additional 250 ml fraction of the sample for Sulfide analysis was placed in a 250 ml pre-cleaned plastic bottle and preserved with NaOH and ZnOAC. Two of the nine samples were field filtered and the 250 ml filtered sample was placed into a pre-cleaned bottle and preserved with HNO_3 and labeled for dissolved arsenic analyses. A 250 ml fraction of each of the remaining seven samples was placed into pre-cleaned 250 ml bottles and unpreserved for laboratory filtering for dissolved arsenic. All containers and preservatives were provided by the analytical laboratory.

Field chain of custody forms were completed at the time of sample collection and field samples were immediately placed in a cooler for transport to the marina where the samples were split into the various fractions and preserved. Samples were then transported to the offices of MATEC in Richmond, Virginia and remained on ice in coolers until shipment. Samples were shipped to ProChem Analytical Services in Roanoke, Virginia by FEDEX on December 3rd and arrived at the laboratory on December 4th. A copy of the analytical report and chain of custody is included in Appendix A of this report.

Samples were analyzed by ProChem within holding times using the following EPA methods of analysis:

- Arsenic (total and dissolved) - Methods 6010B
- Sulfides using USEPA Method 9031

Surface water samples were analyzed for total and dissolved (filtered) arsenic and total sulfides. Since the adjacent surface water bodies are not used for drinking water sources, the most sensitive receptor (most conservative surface water criteria) is aquatic. Therefore, analyses to determine dissolved arsenic concentrations in the surface water were required for aquatic life evaluation. Total arsenic concentrations were determined in surface water to assess human receptor exposures to surface water that includes ingestion and dermal exposure routes. The analytical results are shown in Table 1.

3. Exposure Assessment

A complete exposure pathway exists when there is a constituent present in an environmental media that is in contact with human and/or environmental receptors. Only completed exposure pathways require assessment.

A chain-link fence encloses the majority of the facility. Non-Dominion personnel cannot enter the landfill without authorization. Since the COPCs, specifically arsenic and sulfides are associated with the power generating industry, the Dominion worker exposures to these constituents are considered applicable to OSHA including worker Right to Know and medial monitoring. Non-Dominion or Dominion personnel engaged in soil intrusive activities are considered as potential receptors. Since exposure assumptions and receptors are different for the routine direct contact with soil, the exposure pathway is considered complete for Non-Dominion or Dominion receptors, specifically along the Cooling Water Discharge Canal.

The nearest residences are approximately 2,000 feet to the west and upgradient of the landfill. No public or private water supply wells are known to lie within 1,000 feet of the landfill (EDR, 2003). CEC and structures in the vicinity obtain drinking water from public water supply lines. Groundwater is not used as a drinking water source in the vicinity, therefore this exposure pathway is considered incomplete currently. It is unlikely that the shallow table aquifer will be used for consumptive purposes in the foreseeable future because of the salinity of the groundwater.

There is no known use of the adjacent surface water as domestic water sources (URS, 2003) because adjacent surface water is saline (Dominion Environmental Policy and Compliance-Water-Waste Section, 1996). Based on VAC 25-260-360 the adjacent surface water bodies are not considered public water supplies.

Therefore, the appropriate receptor for surface water exposure pathway would be human (recreationalist) and ecological (aquatic species). While the most stringent exposure pathways and criterion would be chronic aquatic surface water receptors, both human (recreationalists) and aquatic receptor exposure pathways to surface water were evaluated. Based on VAC 25-260-140, the aquatic receptor is marine.

On- and off-site exposure pathways were evaluated for completeness. Since the groundwater discharges to off-site surface water, this pathway is considered complete to off-site human and ecological receptors. The other completed exposure pathway is direct contact with on-site soil. The COPCs are restricted to arsenic and sulfides for surface water and arsenic in soil. The on- and off-site exposure pathways including surface water and soil are included in Table 2.

3.1. COPCs

The two COPCs are arsenic and sulfides. While associated with power generating industry, there are many other sources of both of these COPCs. EPA has recently revised the MCL for arsenic from 50 to 10 ug/L. The criterion for arsenic (dissolved) in marine surface water is 36 ug/L. There is no MCL for total sulfides in groundwater. The sulfide GPS for the CEC has been established at 2.4 mg/L, based on the limit of quantification (LOQ). There is not a "generic" surface water criterion for sulfides.

Arsenic

Arsenic is an element that occurs naturally in the earth's crust at an average concentration of 2–5 mg/kg and is primarily associated with igneous and sedimentary rocks in the form of inorganic arsenic compounds. Background arsenic concentrations in soil range from about 1 to 40 μg/g, with a mean value of about 5 mg/kg. The U.S.Geological Survey reports the mean and range of arsenic in soil and other surficial materials as 7.2 and <0.01–97 mg/kg, respectively (ATSDR, 2000).

While arsenic is released to the environment from natural sources such as wind-blown dirt and volcanoes, releases from anthropogenic sources occurs as well such as nonferrous metal mining and smelting, pesticide application, coal combustion, wood combustion, and waste incineration. Most anthropogenic releases of arsenic are to land or soil, primarily in the form of pesticides or solid wastes. However, amounts are also released to air and water (ATSDR, 2000)

Arsenic released to land is predominantly inorganic and relatively immobile because it binds to soil particles. It is often primarily associated with iron and manganese oxides in soil and does not leach readily to groundwater. While arsenic released from combustion processes will generally occur as highly soluble oxides, environmental conditions will convert it to a more insoluble form. These reactions are influenced by Eh (the oxidation-reduction potential), pH, metal sulfide and sulfide ion concentrations, iron concentration, temperature, salinity, and distribution and composition of the biota. Only soluble forms of arsenic are known to leach into shallow groundwater. When found in groundwater, it is often associated with particulates rather than dissolved (ATSDR, 2000).

In aquatic systems, inorganic arsenic occurs primarily in two oxidation states, As(V) and As(III). Both forms generally exist together although As(V) predominates under oxidizing conditions and As(III) predominates under reducing conditions. Much of the arsenic will adsorb to particulate matter and sediment (ATSDR, 2000).

Sulfides

Sulfides can be an indicator of industrial pollution from multiple sources and are an active regulatory target, particularly for air emissions from industrial operations. Sulfides are also naturally occurring. In analyzing for sulfides, the results reflect all sulfides present in the sample regardless of which type. The potential impact to human health and the environment differs depending upon the speciation.

There is no MCL for total sulfides in groundwater. The sulfide GPS for the landfill has been established at 2.4 mg/L, which has been determined to be the limit of quantification (LOQ). There is not a "generic" surface water criterion for sulfides

3.2. Soil

Tier I

The on-site and background soil sample results were evaluated in accordance with VRP risk assessment guidance. In Tier I, the landfill's maximum arsenic soil concentrations were compared to background maximum concentrations (Table 3). The maximum landfill arsenic concentration (6.2 mg/kg) did not exceed the maximum background concentration (10.8 mg/kg), therefore arsenic was eliminated from further evaluation.

3.3. Groundwater

Tier I

For this evaluation, the landfill's March 2003 groundwater monitoring results were used. Background groundwater data was compared to downgradient data in Tier I (Table 4). Maximum concentrations of arsenic, barium, beryllium, chromium, copper, selenium, sulfides and zinc in at least one downgradient well exceeded background concentrations. It is not unusual for groundwater in this type of soil to have wide ranging background concentrations of inorganics. Nonetheless, these constituents were carried forward in Tier II.

In the March, 2003 monitoring event, one well (CECW2) was found to contain sulfides greater than the GPS (2.6 mg/L versus 2.4 mg/L). Sulfides were not detected in background at concentrations exceeding the method detection limit (MDL) of 0.48 mg/L, therefore sulfides may be present in background but at concentrations below 0.48 mg/L. While the sulfide GPS is not risk-based, sulfides were retained for further evaluation.

Tier II

Based on maximum concentrations, of the eight constituents carried forward in Tier II only arsenic and sulfides were retained for further evaluation as these concentrations exceeded the GPS (Table 5). Historically, the range of arsenic concentrations in the landfill's monitoring wells that exceeded the standard is generally between 50 and 350 ug/L. The arsenic groundwater concentration used in this evaluation is 118 ug/L (PO10) based on the maximum arsenic concentration in the most recent round of groundwater monitoring (March 2003). Groundwater samples from CECW1, CECW6, and PO10 (Table 1, URS groundwater Monitoring Data Report for March 4, 2003) exceeded the current 50 ug/l GPS for arsenic.

With the exception of one well (CECW2), sulfides are either non-detect or below the LOQ and were ("J") flagged as estimated concentrations. There are no health or risk-based criteria available to develop a human health sulfide criterion for groundwater.

Tier III

An acceptable alternative concentration limit (ACL) for the landfill should be protective of promulgated ecological water quality standards. Therefore, the chronic ambient surface water quality criteria for dissolved arsenic (36 ug/L) can serve as the basis for developing the site-specific ACL. In other words, the final concentration in surface water resulting from the groundwater mass discharge to the adjacent surface water bodies should not exceed 36 ug/L.

Using the historic maximum for arsenic (350 ug/L) and the monitoring data for March 4, 2003, the mass discharge to and resultant final concentrations in the adjacent surface water bodies were estimated using conservative assumptions in the Q7-10 and Mean Harmonic Flow (MHF) models. Assuming that the arsenic plume is the entire length of the landfill with groundwater discharging to the surface body that has the most limited flow (Deep Creek), the increased arsenic concentration within the surface water body including that of the background concentration is estimated to be 2-8 ug/L. For the SBER, where there is more dilution of discharge, the predicted arsenic concentration is 1-3 ug/L. It should be noted that this is a conservative comparison since the groundwater data used in the model is based on total arsenic while the surface water criteria is based on dissolved arsenic concentrations. Based on local hydrogeologic conditions (e.g. pH and Eh) the dissolved concentration represents a variable percentage of the total arsenic concentration.

Back calculating using models Q7-10 and MHF to obtain ACLs for groundwater, the maximum arsenic groundwater concentration (and thus the proposed ACL for groundwater at the landfill) could be 1,780 to 18,940 ug/L, depending on the model used.

In general, the Q7-10 model is applied to surface waters destined for domestic use, specifically for those constituents classified as carcinogens. As a conservative measure, selecting the results from the Q7-10 model with the lowest mixing conditions (Deep Creek) and applying aquatic receptors, the ACL for arsenic is 1,780 ug/L for groundwater discharging to Deep Creek and SBER. As a comparison, for the larger water body of the SBER, arsenic discharge concentrations of 8,176 ug/L to 71,042 ug/L using the Q7-10 or MHF model would not exceed the surface water aquatic criteria of 36 ug/l.

The modeling results are presented in Appendix C of this report.

3.4. Surface Water

As noted previously, the exposure pathway to constituents in the shallow groundwater is incomplete, however, the exposure pathway of groundwater migration and discharge to surface water is complete. Transport processes will further dilute groundwater concentrations prior to discharge into the adjacent surface water bodies. As a conservative measure, this process was not included in the risk assessment. Mixing within the surface water would occur depending upon the local flow conditions and this was conservatively modeled using the Q7-10 and MHF models. (Appendix C)

Tier I

Upstream surface water concentrations were compared to landfill-side samples to assess the potential discharge of site groundwater to the adjacent surface water bodies for the specific constituents that were identified as COPC in groundwater, i.e., arsenic and sulfides. Based on recently collected data, the maximum concentration of sulfides in background (2.1 mg/L from Sample ID No.1) located upstream of CEC (within the Deep Creek South Branch) was not exceeded by any of the samples taken along the landfill's reaches of the surface water bodies. Therefore, it can be concluded that sulfide concentrations in surface water bodies adjacent to the landfill are within the concentration range of upstream background (Table 6). Therefore, total sulfide was not retained for further evaluation.

Surface water at two (2) locations (Sample Location 5 and 8) exceeded the maximum background concentration of dissolved arsenic (1.66 ug/L at Sample ID No. 4). These samples contained dissolved arsenic concentrations of 2.16 ug/L and 3.44 ug/L, respectively. Therefore, dissolved arsenic was retained for further evaluation (Table 6).

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Tier II

By regulation, the Tier II screening values for surface water are based on the Virginia Water Quality Criteria (WQC). Since the SBER is tidal, the appropriate criteria are those for marine aquatic receptors. The appropriate saline water criterion for chronic aquatic receptors for dissolved arsenic is 36 ug/L. As found by others (ERP, 2003) dissolved arsenic concentrations in the surface water taken upstream, landfill-side and downstream do not exceed the WQC (Table 7).

Exposures of humans during recreational use of the surface water would be minimal, while aquatic receptors are more sensitive based on the most conservative surface water criteria. Nonetheless, risks associated with exposure to surface water for adults and children (dermal and ingestion) were calculated using the maximum total rather than dissolved arsenic concentration in surface water per VRP guidance. Using conservative exposure assumptions, the estimated risk from the maximum total arsenic concentration in surface water were de minimis (less than 10^{-6}). (Table 8)

3.5. Sediment

While the exposure pathway from groundwater discharge and surface water runoff to sediment is a potentially completed exposure pathway, it was not assessed in this risk evaluation. Based on the on-site soil and surface water concentrations of COPCs and the evaluation of risks provided above, it is unlikely that the exposures experienced by trespassers, recreationalists or benthic organisms in contact with sediment in surface water on or adjacent to the landfill would be impacted adversely and/or experience exposures any greater than that of background conditions.

VRP guidance indicates that risk-based sediment criteria are 10x greater than the Tier II soil screening criteria (non-restrictive or residential criteria). Based on the arsenic surface soil data reviewed for this assessment, arsenic in soil that may be transported from the on-site areas sampled into surface water would present similar exposure conditions as background. Based on VRP Tier II arsenic criterion, the arsenic in soil/sediment would not pose an unacceptable risk.

4. Summary and Conclusions

Data from three media (soil, surface water and groundwater) were screened to determine if constituent concentrations in these media posed an unacceptable risk to human health and the environment. The evaluation was limited to inorganics and sulfide in groundwater, inorganics in soil and arsenic (total and dissolved) and sulfide in surface water.

Soil –.The arsenic concentrations in the soil on the landfill reviewed for this assessment are consistent with background. Based on the land use (industrial) and the limited exposures to soil that may occur with non-Dominion personnel, there is no unacceptable risk to receptors from arsenic in soil as the concentrations are less than that of background.

Groundwater – Groundwater samples were in concentrations either greater than background and/or exceeding the GPS for two constituents, i.e., arsenic and sulfide. The groundwater under the site is not potable and no nearby wells were located so the exposure pathway is incomplete. An institutional control can be placed on the property that would ensure that groundwater would not be used in a manner that provided ingestion and dermal contact exposure pathways.

Based on DEQ's Guidance for developing GPS the acceptable alternative concentration limit (ACL) for the landfill should be protective of promulgated ecological standards. Therefore, the chronic ambient water quality criteria for dissolved arsenic (36 ug/L) can serve as the basis for developing the site-specific ACL. The final concentration in surface water resulting from the groundwater mass discharge to the adjacent surface water bodies should not exceed 36 ug/L. Using the Q7-10 model with conservative assumptions, the proposed arsenic ACL is 1,780 ug/L for groundwater discharging to Deep Creek and SBER.

Since the GPS for sulfide at the landfill has been established at 2.4 mg/L, Dominion may consider petitioning for a variance to increase the levels to the maximum detected in the background wells or alternatively, a site-specific criterion may be developed using the same method applied to arsenic but using the maximum upstream background sulfide concentration as the "not to exceed" final surface water concentration.

Surface Water – As found by others (ERP, 2003) dissolved arsenic concentrations in the surface water taken upstream, landfill-side and downstream do not exceed the WQC. Using conservative exposure assumptions, the estimated risk from the maximum total arsenic concentration in surface water were de minimis (less than 10^{-6}) for all total arsenic surface water concentrations.

WQS have not been established for total sulfides. The maximum concentration of sulfides were found in background (2.1 mg/L from Sample ID No.1) located upstream of CEC within the Southern Branch of Deep Creek. Background concentrations were not exceeded by any of the samples taken along the landfill's reaches of the surface water bodies. Therefore, it appears that the CEC groundwater contribution to total sulfide concentrations in adjacent surface water bodies is minimal and poses little risk to existing environmental conditions.

5. References

ATSDR 2000, Toxicological Profile for Arsenic.
ERP, 2003, State of the River 2003, Elizabeth River Project
EPA, 2001, Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.
URS, Groundwater Monitoring Data Report, 2003a
URS, Assessment of Corrective Measures, 2003b

Appendix A - Tables

Table 1: Analytical Summary
Dominion Energy- Chesapeake Energy Center
Surface Water Sampling
December 6 -7, 2003

Sample Identification	Sample Location Description	Arsenic, Total (µg/l)	Arsenic, Dissolved (µg/l)	Sulfide (mg/l)
#1	Deep Creek South Branch Upstream of CEC	3.28	<0.90	2.1
#2	Deep Creek at CEC	1.13	<0.90	<1.0
#3	Upstream of CEC on South Branch Elizabeth River – West	<0.90	<0.90	1.1
#4	Upstream of CEC on South Branch Elizabeth River East	2.28	1.66	<1.0
#5	CEC Discharge Canal	3.09	2.16	1.1
#6	Deep Creek Upstream	<0.90	<0.90	<1.0
#7	Entrance to Discharge Canal	2.09	1.10	<1.0
#8	Elizabeth River Downstream of CEC- West	3.15	1.74	1.1
#9	Elizabeth River Downstream on CEC -East	<0.90	<0.90	<1.0

Table 2 Selection of Exposure Pathways

Medium	Exposure Medium	Receptor Population	Receptor Age	Exposure Route	Rationale for Selection or Exclusion of Exposure Pathway
Groundwater	Groundwater	Resident	Adult	Dermal	Not complete = no wells identified and groundwater not potable - Industrial land use
				Ingestion	Not complete = no wells identified and groundwater not potable - Industrial land use
			Child	Dermal	Not complete = no wells identified and groundwater not potable - Industrial land use
				Ingestion	Not complete = no wells identified and groundwater not potable - Industrial land use
	Shower Air		Adult	Inhalation	Not complete = no volatiles identified as COPCs
	Building Air		Adult	Inhalation	Not complete = no volatiles identified as COPCs
			Child	Inhalation	Not complete = no volatiles identified as COPCs
	Groundwater	Construction Worker	Adult	Dermal	Not complete = no wells identified and groundwater not potable
				Ingestion	Not complete = no wells identified and groundwater not potable
	Air			Inhalation	Not complete -= no volatiles identified as COPCs
	Groundwater	Commercial/ Industrial	Adult	Dermal	Not complete = no wells identified and groundwater not potable
				Ingestion	Not complete = no wells identified and groundwater not potable
	Building Air			Inhalation	Not complete -= no volatiles identified as COPCs
Surface Water	Surface Water	Recreational/ Trespasser	Adult	Dermal	Complete but minimal exposure/de minimus risk (<10-6) or equal to background
				Ingestion	Complete but minimal exposure/de minimus risk (<10-6) or equal to background
			Child	Dermal	Complete but minimal exposure/de minimus risk (<10-6) or equal to background
				Ingestion	Complete but minimal exposure/de minimus risk (<10-6) or equal to background
	Aquatic Organisms		Adult	Ingestion	Complete but minimal exposure - COPCs not bioaccumulative = background
			Child	Ingestion	Complete but minimal exposure - COPCs not bioaccumulative

Table 2 Selection of Exposure Pathways

Medium	Exposure Medium	Receptor Population	Receptor Age	Exposure Route	Rationale for Selection or Exclusion of Exposure Pathway
Soil	Soil	Resident	Adult	Dermal	Not complete - Industrial land use
				Ingestion	Not complete - Industrial land use
			Child	Dermal	Not complete - Industrial land use
				Ingestion	Not complete - Industrial land use
	Air		Adult	Inhalation	Not complete - no volatiles identified as COPCs
			Child	Inhalation	Not complete - no volatiles identified as COPCs
	Soil	Trespasser/Visitor	Adult	Dermal	Complete
				Ingestion	Complete
			Child	Dermal	Complete
				Ingestion	Complete
	Air		Adult	Inhalation	Incomplete - no volatiles identified
			Child	Inhalation	Incomplete - no volatiles identified
	Soil	Construction Worker	Adult	Dermal	Complete
				Ingestion	Complete
	Air			Inhalation	Incomplete - no volatiles identified
	Soil	Commercial/ Industrial	Adult	Dermal	Complete
				Ingestion	Complete
	Air			Inhalation	Incomplete - no volatiles identified
Sediment	Sediment	Recreational/ Trespasser	Adult	Dermal	Potentially complete - Not accessed - minimal exposure potential - likely similar to background conditions
				Ingestion	Potentially complete - Not accessed - minimal exposure potential - likely similar to background conditions
			Child	Dermal	Potentially complete - Not accessed - minimal exposure potential - likely similar to background conditions
				Ingestion	Potentially complete - Not accessed - minimal exposure potential - likely similar to background conditions
	Aquatic Organisms		Adult	Ingestion	Potentially complete - Not accessed - minimal exposure potential - likely similar to background conditions
			Child	Ingestion	Potentially complete - Not accessed - minimal exposure potential - likely similar to background conditions

Table 3 Selection of Contaminants of Concern Soil	Background Concentration mg/kg	Soil Concentration mg/kg	Contaminant Of Potential Concern?
Inorganics			
Arsenic	10.8	6.2	No
Barium	89.3	70.6	No
Cadmium	0.455*	0.86	Yes
Chromium	17.2	38.7	Yes
Lead	57.9	137	Yes
Mercury	0.17	0.23	Yes
Selenium	2.3	0.98	No
Silver	0.9*	0.8*	No

Table 4
Selection of Contaminants of Concern Groundwater

	Background Concentration mg/l	Groundwater Concentration mg/l	Contaminant Of Potential Concern?
Inorganics			
Antimony	0.005	0.004	no
Arsenic	0.012	0.118	yes
Barium	0.021	0.26	yes
Beryllium	0.0001	0.0013	yes
Cadmium	0.00015*	0.00015*	no
Chromium	0.004	0.04	yes
Cobalt	0.0015*	0.0015*	no
Copper	0.007	0.012	yes
Lead	0.002	0.0005*	no
Nickel	0.041	0.021	no
Selenium	0.0015*	0.037	yes
Silver	0.00015*	0.0002	no
Sulfide	0.24*	2.6	yes
Thallium	0.001*	0.001*	no
Vanadium	1.892	0.804	no
Zinc	0.005*	0.026	yes

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Table 5 Selection of Contaminants of Concern Groundwater: Unrestricted (Residential)	CAS No.	Maximum Contaminant Level MCL ug/L	RBC Tap Water (a) ug/L	VRP Tier II Screening Level ug/L	Ground Water Maximum Concentration ug/L	Contaminant of Potential Concern?
Inorganics						
Arsenic	7440-38-2	10	0.045	10	110	yes
Barium	7440-39-3	2000	260	2000	260	no
Beryllium	7440-41-7	4	7.3	4	1.3	no
Chromium	7440-47-3	100	11 (b)	100	40	no
Copper	7440-50-8	1300 (c)	150	1300	12	no
Selenium	7782-49-2	50	18	50	37	no
Sulfides		2400		2400	2600	yes
Zinc	7440-66-6		1100	1100	26	no

(a) Multiplied by 0.1 for noncarcinogens
(b) See Risk-Based Screening Levels Proxy Values in Appendix
(c) Action Level
(d) Value calculated by multiplying the MCL for 2,3,7,8-TCDD
by a toxicity equivalency factor (TEF) of 10
! Noncarcinogenic RBC < carcinogenic RBC @ THQ=0.1
RBC Risk-Based Concentration

Table 6:

Selection of Contaminants of Concern
Surface Water

	Background Concentration ug/l	Surface Water Concentration ug/l	Contaminant Of Potential Concern?
Inorganics			
Dissolved Arsenic	1.66	3.44	yes
Total Arsenic	3.28	3.09	no
Sulfides	2100	1100	no

Table 7

Selection of Contaminants of Concern Other Surface Water - Marine	CAS No.	Federal WQC Marine CCC ug/L	Federal WQC Fish Ingestion Only ug/L	VA Water Quality Standards Marine Chronic ug/L	VA Water Quality Standards Other ug/L	VRP Tier II Screening Level ug/L	Surface Water Maximum Concentration ug/L	Contaminant of Potential Concern?
Inorganics								
Arsenic	7440-38-2	36	0.14	36		36	3.44	no

Table 8
CALCULATION OF CANCER RISKS
REASONABLE MAXIMUM EXPOSURE AND CENTRAL TENDENCY
RESIDENT (ON-SITE)
South Branch Elizabeth River/ Deep Creek
CEC
Chesapeake, Virginia

Scenario Timeframe: Future
Medium: Surface Water
Exposure Medium: Surface Water
Exposure Point: Surface Water
Receptor Population: Resident (On-Site)
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	RME EPC Value	RME EPC Units	CT EPC Value	CT EPC Units	RME Intake (Cancer) (mg-kg-day)	CT Intake (Cancer) (mg-kg-day)	Cancer Slope Factor	Cancer Slope Factor Units	RME Cancer Risk	CT Cancer Risk
Ingestion	1,1,1-Trichloroethane	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	1,1'-Biphenyl	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	1,3,5-Trinitrobenzene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	2,4,5-Trichlorophenol	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	2,4,6-Trinitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	3.00E-02	(mg/kg-day)-1	0.00E+00	0.00E+00
	2,4-Dinitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	6.80E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	2,6-Dinitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	6.80E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	2-Amino-4,6-Dinitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	6.80E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	2-Butanone	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	2-Methylnaphthalene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	2-Nitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	4,4'-DDD	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	2.40E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	4,4'-DDE	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	3.40E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	4,4'-DDT	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	3.40E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	4-Amino-2,6-dinitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	6.80E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Acenaphthene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Acenaphthylene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Acetone	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Aldrin	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.70E+01	(mg/kg-day)-1	0.00E+00	0.00E+00
	alpha-BHC	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	6.30E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	alpha-Chlordane	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	3.50E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Aluminum	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Anthracene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Antimony	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Arsenic	3.09E-03	mg/l	0.00E+00	mg/l	3.45E-07	0.00E+00	1.50E+00	(mg/kg-day)-1	5.17E-07	0.00E+00
	Barium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Benzaldehyde	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Benzo(a)anthracene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Benzo(a)pyrene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Benzo(b)fluoranthene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E-01	(mg/kg-day)-1	0.00E+00	0.00E+00

Table 8

CALCULATION OF CANCER RISKS
REASONABLE MAXIMUM EXPOSURE AND CENTRAL TENDENCY
RESIDENT (ON-SITE)
South Branch Elixabeth River/ Deep Creek
CEC
Chesapeake, Virginia

Scenario Timeframe: Future
Medium: Surface Water
Exposure Medium: Surface Water
Exposure Point: Surface Water
Receptor Population: Resident (On-Site)
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	RME EPC Value	RME EPC Units	CT EPC Value	CT EPC Units	RME Intake (Cancer) (mg-kg-day)	CT Intake (Cancer) (mg-kg-day)	Cancer Slope Factor	Cancer Slope Factor Units	RME Cancer Risk	CT Cancer Risk
	Benzo(g,h,i)perylene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Benzo(k)fluoranthene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E-02	(mg/kg-day)-1	0.00E+00	0.00E+00
	Beryllium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Bis(2-ethylhexyl)phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.40E-02	(mg/kg-day)-1	0.00E+00	0.00E+00
	Butylbenzyl phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Cadmium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Calcium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Carbazole	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	2.00E-02	(mg/kg-day)-1	0.00E+00	0.00E+00
	Carbon Disulfide	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Chloromethane	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.30E-02	(mg/kg-day)-1	0.00E+00	0.00E+00
	Chromium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Chrysene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E-03	(mg/kg-day)-1	0.00E+00	0.00E+00
	cis-1,2-Dichloroethene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Cobalt	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Copper	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Cyanide	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Cyclohexanone	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	delta-BHC	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.80E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Dibenz(a,h)anthracene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Dibenzofuran	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Dieldrin	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.60E+01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Diethyl phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Dimethyl phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Di-n-butyl phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Di-n-octyl phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Endosulfan II	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Endosulfan sulfate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Endrin	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Endrin aldehyde	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Endrin ketone	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00

Table 8
CALCULATION OF CANCER RISKS
REASONABLE MAXIMUM EXPOSURE AND CENTRAL TENDENCY
RESIDENT (ON-SITE)
South Branch Elixabeth River/ Deep Creek
CEC
Chesapeake, Virginia

Scenario Timeframe: Future
Medium: Surface Water
Exposure Medium: Surface Water
Exposure Point: Surface Water
Receptor Population: Resident (On-Site)
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	RME EPC Value	RME EPC Units	CT EPC Value	CT EPC Units	RME Intake (Cancer) (mg-kg-day)	CT Intake (Cancer) (mg-kg-day)	Cancer Slope Factor	Cancer Slope Factor Units	RME Cancer Risk	CT Cancer Risk
	Fluoranthene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Fluorene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	gamma-Chlordane	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	3.50E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Heptachlor	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	4.50E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Heptachlor Epoxide	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	9.10E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	HMX	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.10E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Indeno(1,2,3-cd)pyrene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Iron	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Lead	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Magnesium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Manganese	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Mercury	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Methoxychlor	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Methylene chloride	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.50E-03	(mg/kg-day)-1	0.00E+00	0.00E+00
	Naphthalene	0.00E+00	mg/l	4.03E-05	mg/l	0.00E+00	4.22E-10	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Nickel	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	N-Nitrosodiphenylamine	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	4.90E-03	(mg/kg-day)-1	0.00E+00	0.00E+00
	Pentachlorophenol	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.20E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Phenanthrene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Potassium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Pyrene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	RDX	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.10E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Selenium	0.00E+00	mg/l	1.93E-03	mg/l	0.00E+00	2.02E-08	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Silver	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Sodium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Tetryl	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.60E-03	(mg/kg-day)-1	0.00E+00	0.00E+00
	Thallium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	TOC	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Toluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Xylenes, total	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00

Table 8
CALCULATION OF CANCER RISKS
REASONABLE MAXIMUM EXPOSURE AND CENTRAL TENDENCY
RESIDENT (ON-SITE)
South Branch Elixabeth River/ Deep Creek
CEC
Chesapeake, Virginia

Scenario Timeframe: Future
Medium: Surface Water
Exposure Medium: Surface Water
Exposure Point: Surface Water
Receptor Population: Resident (On-Site)
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	RME EPC Value	RME EPC Units	CT EPC Value	CT EPC Units	RME Intake (Cancer) (mg-kg-day)	CT Intake (Cancer) (mg-kg-day)	Cancer Slope Factor	Cancer Slope Factor Units	RME Cancer Risk	CT Cancer Risk
Dermal	Trichloroethene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	4.00E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Vanadium	0.00E+00	mg/l	2.36E-02	mg/l	0.00E+00	2.47E-07	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Zinc	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	1,1,1-Trichloroethane	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	1,1'-Biphenyl	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	1,3,5-Trinitrobenzene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	2,4,5-Trichlorophenol	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	2,4,6-Trinitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	3.00E-02	(mg/kg-day)-1	0.00E+00	0.00E+00
	2,4-Dinitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	6.80E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	2,6-Dinitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	6.80E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	2-Amino-4,6-Dinitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	6.80E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	2-Butanone	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	2-Methylnaphthalene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	2-Nitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	4,4'-DDD	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	2.40E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	4,4'-DDE	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	3.40E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	4,4'-DDT	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	3.40E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	4-Amino-2,6-dinitrotoluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	6.80E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Acenaphthene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Acenaphthylene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Acetone	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Aldrin	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.70E+01	(mg/kg-day)-1	0.00E+00	0.00E+00
	alpha-BHC	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	6.30E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	alpha-Chlordane	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	3.50E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Aluminum	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Anthracene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Antimony	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Arsenic	3.09E-03	mg/l	0.00E+00	mg/l	3.45E-08	0.00E+00	1.50E+00	(mg/kg-day)-1	5.17E-08	0.00E+00
	Barium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Benzaldehyde	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00

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Exposure Route	Chemical of Potential Concern	RME EPC Value	RME EPC Units	CT EPC Value	CT EPC Units	RME Intake (Cancer) (mg-kg-day)	CT Intake (Cancer) (mg-kg-day)	Cancer Slope Factor	Cancer Slope Factor Units	RME Cancer Risk	CT Cancer Risk
	Benzo(a)anthracene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Benzo(a)pyrene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Benzo(b)fluoranthene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Benzo(g,h,i)perylene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Benzo(k)fluoranthene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E-02	(mg/kg-day)-1	0.00E+00	0.00E+00
	Beryllium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Bis(2-ethylhexyl)phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.40E-02	(mg/kg-day)-1	0.00E+00	0.00E+00
	Butylbenzyl phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Cadmium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Calcium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Carbazole	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	2.00E-02	(mg/kg-day)-1	0.00E+00	0.00E+00
	Carbon Disulfide	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Chloromethane	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.30E-02	(mg/kg-day)-1	0.00E+00	0.00E+00
	Chromium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Chrysene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E-03	(mg/kg-day)-1	0.00E+00	0.00E+00
	cis-1,2-Dichloroethene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Cobalt	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Copper	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Cyanide	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Cyclohexanone	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	delta-BHC	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.80E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Dibenz(a,h)anthracene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Dibenzofuran	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Dieldrin	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.60E+01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Diethyl phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Dimethyl phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Di-n-butyl phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Di-n-octyl phthalate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Endosulfan II	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Endosulfan sulfate	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00

Table 8
CALCULATION OF CANCER RISKS
REASONABLE MAXIMUM EXPOSURE AND CENTRAL TENDENCY
RESIDENT (ON-SITE)
South Branch Elixabeth River/ Deep Creek
CEC
Chesapeake, Virginia

Scenario Timeframe: Future
Medium: Surface Water
Exposure Medium: Surface Water
Exposure Point: Surface Water
Receptor Population: Resident (On-Site)
Receptor Age: Adult

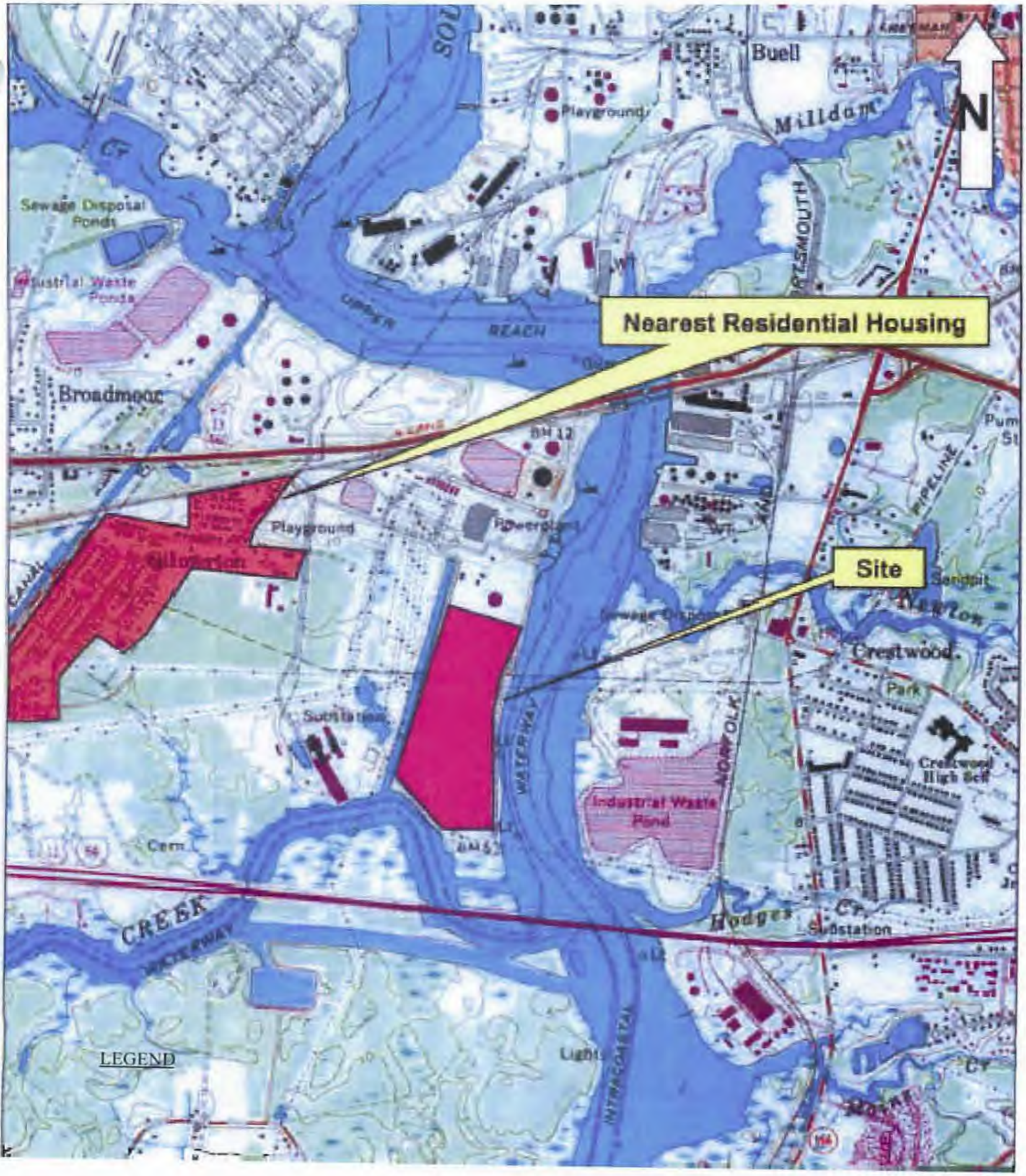
Exposure Route	Chemical of Potential Concern	RME EPC Value	RME EPC Units	CT EPC Value	CT EPC Units	RME Intake (Cancer) (mg-kg-day)	CT Intake (Cancer) (mg-kg-day)	Cancer Slope Factor	Cancer Slope Factor Units	RME Cancer Risk	CT Cancer Risk
	Endrin	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Endrin aldehyde	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Endrin ketone	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Fluoranthene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Fluorene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	gamma-Chlordane	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	3.50E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Heptachlor	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	4.50E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Heptachlor Epoxide	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	9.10E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	HMX	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.10E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Indeno(1,2,3-cd)pyrene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.30E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Iron	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Lead	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Magnesium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Manganese	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Mercury	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Methoxychlor	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Methylene chloride	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.50E-03	(mg/kg-day)-1	0.00E+00	0.00E+00
	Naphthalene	0.00E+00	mg/l	4.03E-05	mg/l	0.00E+00	2.93E-09	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Nickel	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	N-Nitrosodiphenylamine	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	4.90E-03	(mg/kg-day)-1	0.00E+00	0.00E+00
	Pentachlorophenol	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.20E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Phenanthrene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Potassium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Pyrene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	RDX	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	1.10E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Selenium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Silver	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Sodium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Tetryl	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	7.60E-03	(mg/kg-day)-1	0.00E+00	0.00E+00
	Thallium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00

Table 8
CALCULATION OF CANCER RISKS
REASONABLE MAXIMUM EXPOSURE AND CENTRAL TENDENCY
RESIDENT (ON-SITE)
South Branch Elixabeth River/ Deep Creek
CEC
Chesapeake, Virginia

Scenario Timeframe: Future
Medium: Surface Water
Exposure Medium: Surface Water
Exposure Point: Surface Water
Receptor Population: Resident (On-Site)
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	RME EPC Value	RME EPC Units	CT EPC Value	CT EPC Units	RME Intake (Cancer) (mg-kg-day)	CT Intake (Cancer) (mg-kg-day)	Cancer Slope Factor	Cancer Slope Factor Units	RME Cancer Risk	CT Cancer Risk
	TOC	0.00E+00	mg/l	0.00E+00	mg/l	NA	NA	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Toluene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Xylenes, total	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Trichloroethene	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	4.00E-01	(mg/kg-day)-1	0.00E+00	0.00E+00
	Vanadium	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
	Zinc	0.00E+00	mg/l	0.00E+00	mg/l	0.00E+00	0.00E+00	0.00E+00	(mg/kg-day)-1	0.00E+00	0.00E+00
									Total Excess Lifetime Cancer Risk (ELCR):	5.69E-07	0.00E+00

Appendix B – Figures



MACTEC

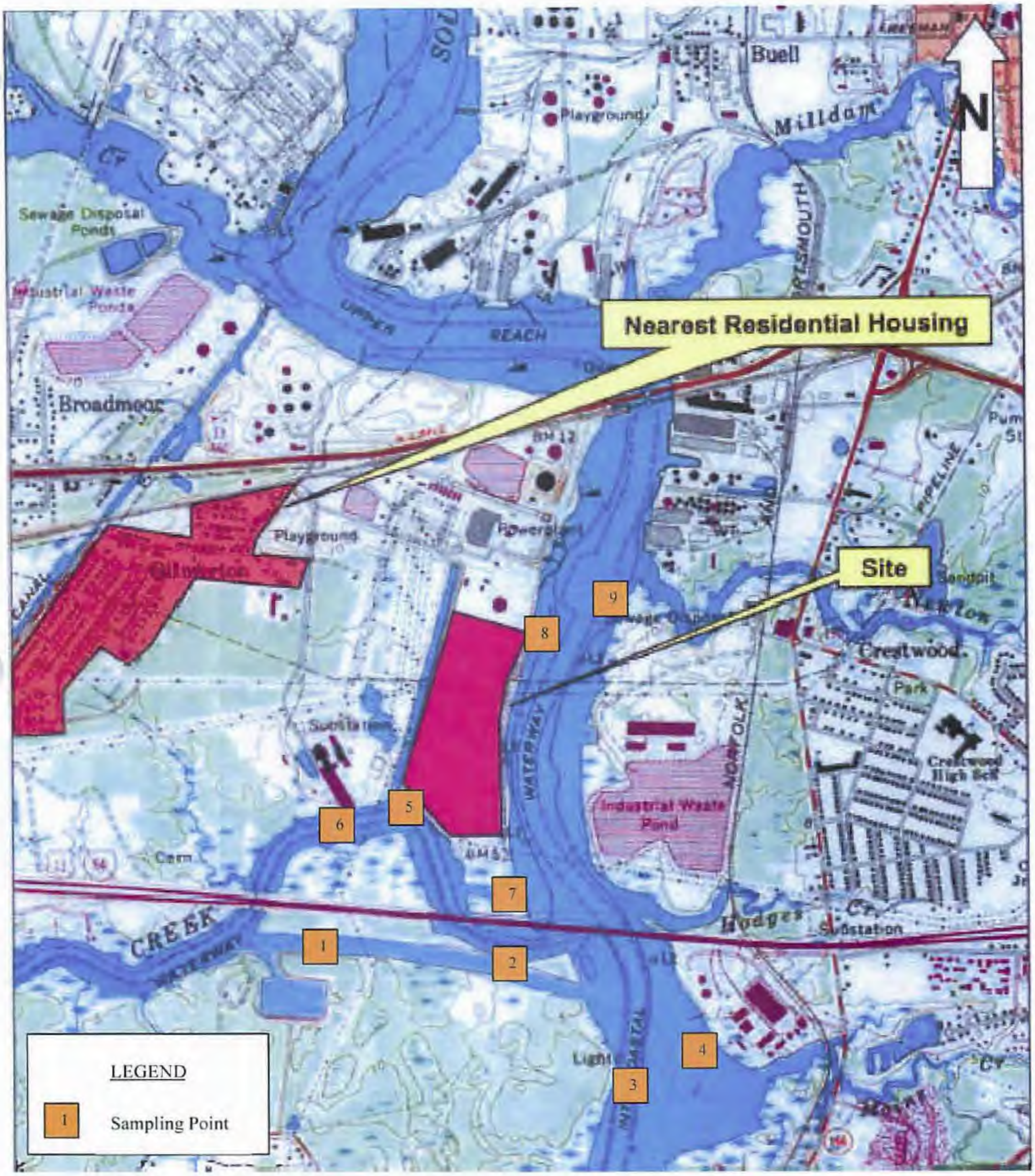
ENGINEERING AND CONSULTING, INC.
1606 Ownby Lane, Richmond, VA 23220

DES. BY	T.A.W.
DRN. BY	T.A.W.
REV. BY	S.R.P.

Figure 1 – Site Location Map

Dominion, Chesapeake Energy Center
Chesapeake, Virginia
Norfolk South Quadrangle, Virginia

Project # 3530-03-1266 December, 2003



DES. BY	T.A.W.
DRN. BY	T.A.W.
REV. BY	S.R.P.

MACTEC
ENGINEERING AND CONSULTING, INC.
1606 Ownby Lane, Richmond, VA 23220

Figure 1 – Sample Location Map

Dominion, Chesapeake Energy Center
Chesapeake, Virginia
Norfolk South Quadrangle, Virginia

Project # 3530-03-1266 December, 2003

Appendix C – Surface Water Models

Evaluation of Groundwater - Surface water Mixing

I) Estmate of Groundwater discharge

$$Q_{GW} = (K * i * A)$$

K = Hydraulic conductivity
i = Hydraulic gradient
A = Cross-Sectional Area of Plume {A = (b * w)}
b = Aquifer saturated thickness (contaminated)
w = width of contaminated plume
n = effective porosity of saturated material

input

	Shallow			
K =	1.00E-05	cm/sec		
i =	0.25	ft/ft		
V =	1.14E-06	ft/sec	1.5	ft/year
b =	60	ft		
w =	1000	ft		
n =	0.2	percent		

Q_{GW} = 9.84E-04 cfs

II) Estimate of surface water discharge

Stream: **Deep Creek**

Basin Size	50	sq. miles	
$Q_{7\text{-}10}$ factor	0.001	cfs per square mile	USGS Reports "approximately 0.0 cfs" for this region

	$Q_{7\text{-}10}$	Mean Harmonic Flow
Q_{SW} =	**0.1 cfs**	**0.5 cfs**

III) Estimate of in-stream concentration

$$C_{mix} = ((C_{GW} * Q_{GW}) + (C_{SW} * Q_{SW})) / (Q_{GW} + Q_{SW})$$

C_{mix}	Mixed concentration in creek following groundwater discharge
C_{GW}	Concentration of contaminant in groundwater
C_{SW}	Concentration of contaminant in surface water prior to mixing
Q_{GW}	Groundwater discharge
Q_{SW}	Surface water discharge

Symbol	Value	Units		
		$Q_{7\text{-}10}$	**Mean Harmonic Flow**	
C_{GW}	0.35	mg/l	0.35	mg/l
C_{SW}	0.00166	mg/l	0.00166	mg/l
Q_{GW}	0.000984	cfs	0.0009843	cfs
Q_{SW}	0.1	cfs	0.5	cfs

C_{mix}	0.008385 mg/l	0.002292 mg/l

IV) Back calculation of critical groundwater threshold concentration

$C_{GW} = ((C_{mix} * (Q_{GW} + Q_{SW})) - (C_{SW} * Q_{SW})) / Q_{GW}$

Input: **Maximum Allowable concentration in creek:**

C_{mix} 0.036 mg/l

	$Q_{7\text{-}10}$	Mean Harmonic Flow
C_{GW} =	1.780387 mg/l	18.940335 mg/l

Evaluation of Groundwater - Surface water Mixing

I) Estmate of Groundwater discharge

$Q_{GW} = (K * i * A)$

K = Hydraulic conductivity
i = Hydraulic gradient
A = Cross-Sectional Area of Plume {A = (b * w)}
b = Aquifer saturated thickness (contaminated)
w = width of contaminated plume
n = effective porosity of saturated material

input	**Shallow**		
K =	1.00E-05	cm/sec	
i =	0.25	ft/ft	
V =	3.81E-06	ft/sec	5 ft/year
b =	60	ft	
w =	1200	ft	
n =	0.2	percent	
Q_{GW} =	1.18E-03	**cfs**	

II) Estimate of surface water discharge

Stream: **Southern Branch Elizabeth River**

Basin Size	280	sq. miles	
Q_{7-10} factor	0.001	cfs per square mile	USGS Reports "approximately 0.0 cfs" for this region

	Q_{7-10}	Mean Harmonic Flow
Q_{SW} =	0.3 **cfs**	2.4 **cfs**

III) Estimate of in-stream concentration

$C_{mix} = ((C_{GW} * Q_{GW}) + (C_{SW} * Q_{SW})) / (Q_{GW} + Q_{SW})$

C_{mix}	Mixed concentration in creek following groundwater discharge
C_{GW}	Concentration of contaminant in groundwater
C_{SW}	Concentration of contaminant in surface water prior to mixing
Q_{GW}	Groundwater discharge
Q_{SW}	Surface water discharge

Symbol	Value	Units	**Mean Harmonic Flow**	
		Q_{7-10}		
C_{GW}	0.35	mg/l	0.35	mg/l
C_{SW}	0.00166	mg/l	0.00166	mg/l
Q_{GW}	0.001181	cfs	0.00118116	cfs
Q_{SW}	0.3	cfs	2.4	cfs

C_{mix}	0.003123 **mg/l**	0.001828 **mg/l**

IV) Back calculation of critical groundwater threshold concentration

$C_{GW} = ((C_{mix} * (Q_{GW} + Q_{SW})) - (C_{SW} * Q_{SW})) / Q_{GW}$

Input: **Maximum Allowable concentration in creek:**

C_{mix} 0.036 mg/l

	$Q_{7\text{-}10}$	**Mean Harmonic Flow**
C_{GW} =	8.176472 **mg/l**	71.0422362 **mg/l**

Attachment G
Arsenic Speciation Analytical Results

**APPLIED SPECIATION
AND CONSULTING, LLC**

953 Industry Drive Tukwila, WA 98188
Tel: (206) 219-3779 Fax: (206) [illegible]
www.appliedspeciation.com

February 27, 2006

Montgomery Bennett
GES
23 South 13th Street, Suite 201
Richmond, VA 23219
(804) 343-0700

Project Name: CEC Landfill

Dear Mr. Bennett,

Attached is the report associated with five (5) groundwater samples (two fractions per sample) submitted on February 14, 2006 for total As analyses. All samples were received on February 15, 2006. The following report outlines the applied methodologies for sample preparation, analysis, and any encountered variances.

If you have any questions, please feel free to contact me at your convenience.

Sincerely,

Russell Gerads
Vice President
Applied Speciation and Consulting, LLC

Applied Speciation and Consulting, LLC

Report Prepared for:

Montgomery Bennett
GES
23 South 13th Street, Suite 201
Richmond, VA 23219

Project Name: CEC Landfill

February 27, 2006

1. Sample Reception

Five (5) groundwater samples, in two separate fractions, were submitted for total As quantitation on February 14, 2006. All samples were received in acceptable condition on February 15, 2006 in a sealed container at ambient temperature.

The samples were received in a laminar flow clean hood void of trace metals contamination and ultra-violet radiation. Upon reception, the samples were designated discrete sample identifiers, preserved to 1% HNO_3 (v/v), and were stored in a secure container prior to total As analysis via inductively coupled plasma dynamic reaction cell mass spectrometry (ICP-DRC-MS).

2. Sample Preparation

All sample preparation is performed in laminar flow clean hoods known to be free from trace metals contamination. All applied water for dilutions and sample preservatives are monitored for contamination to account for any biases associated with the sample results.

It should be noted that two fractions were submitted for each sample. One sample fraction was designated as As(III) and the other sample fraction was designated as total As. All samples fractions were handled in the same fashion upon reception.

Trace Metals Quantification by ICP-DRC-MS Prior to analysis, all samples were preserved to 1% HNO_3 (v/v) followed by a closed vessel oven digestion. Immediately prior to analysis the pH for all samples was checked to be pH <1. All samples were then analyzed by ICP-DRC-MS.

3. Sample Analysis

All sample analysis is precluded by a minimum of a five-point calibration curve spanning the entire concentration range of interest. Calibration curves are performed at the beginning of each analytical day. All calibration curves, associated with each species of interest, are standardized by linear regression resulting in a response factor. All sample results are instrument blank corrected only to account for any operational biases.

Prior to sample analysis, all calibration curves are verified using second source standards which are identified as initial calibration verification standards (ICV).

Ongoing instrument performance is identified by the analysis of continuing calibration verification standards (CCV) and continuing calibration blanks (CCB) at a minimal interval of every ten analytical runs.

Trace Metals Quantification by ICP-DRC-MS All samples for total As quantification were analyzed by inductively coupled plasma dynamic reaction cell mass spectrometry (ICP-DRC-MS). Aliquots of each sample are introduced into a radio frequency (RF) plasma where energy-transfer processes cause desolvation, atomization, and ionization. The ions are extracted from the plasma through a differentially-pumped vacuum interface and travel through a pressurized chamber (DRC) containing a specific reactive gas which preferentially reacts with interfering ions producing different mass to charge ratios (m/z) which can then be differentiated from the target analytes. A solid-state detector detects ions transmitted through the mass analyzer, on the basis of their mass-to-charge ratio (m/z), and the resulting current is processed by a data handling system.

4. Analytical Issues

The overall analyses went very well and no significant analytical issues were encountered. All quality control parameters associated with these samples were within acceptance limits.

All results associated with this report have been continuing calibration verification (CCV) corrected to account for any perceived instrument bias.

The first preparation blank has been identified as a statistical outlier according to the Grubb's Test. This blank was not applied for calculation of the estimated method detection limit (eMDL)or any other calculations associated with this report.

Please feel free to contact me with any questions or concerns regarding this report (206) 219-3779.

Sincerely,

Russell Gerads
Vice President
Applied Speciation and Consulting, LLC

Trace Metals Results for GES
Contact: Montgomery Bennet

Date: February 27, 2006
Report Generated by: Russell Gerads
Applied Speciation and Consulting, LLC

Sample Results

Sample ID	Dilution	Total As	As(III)	As(V)*
CECW-6I	25	367	299	68
PO-10	25	113	105	8
MW-5	25	3.99	1.79	2.20
CECW-1I	25	165	156	9
CECW-1D	25	24.1	29.7	ND (<0.60)

All results reflect the applied dilution and are reported in µg/L
*As(V) is calculated by difference: Total As - As(III)

Trace Metals Results for GES
Contact: Montgomery Bennett

Date: February 27, 2006
Report Generated by: Russell Gerads
Applied Speciation and Consulting, LLC

Quality Control Summary - Preparation Blank Summary

Analyte (µg/L)	PBW1	PBW2	PBW3	PBW4	Mean	StdDev	eMDL	eMDL 25x
As	*	0.01	0.02	0.01	0.02	0.01	0.028	0.60

eMDL = Estimated Method Detection Limit

*The preparation blank has been identified as a statistical outlier according to the Grubb's Test.

Quality Control Summary - Certified Reference Materials

Analyte (µg/L)	CRM	True Value	Result	Recovery
As	NIST 1640	26.67	26.78	100.4

Quality Control Summary - Matrix Duplicates

Analyte (µg/L)	Sample ID	Rep 1	Rep 2	Mean	RPD
As	PO-10 [As(III)]	105.1	106.3	105.7	1.2

Quality Control Summary - Matrix Spike/ Matrix Spike Duplicate

Analyte (µg/L)	Sample ID	Spike Conc	MS Result	Recovery	Spike Conc	MSD Result	Recovery	RPD
As	PO-10 [As(III)]	250.0	388.5	113.1	250.0	386.9	112.5	0.4

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES
NEW MEXICO TECH
801 LEROY PLACE, SOCORRO, NM 87801
PH: 505-835-5160 FAX: 505-835-6333

REPORT OF ANALYSES

Name	Greg Miller
Address	Subsurface Technologies
Address 2	40 Stone Castle Road
City, State, Zip code	Rock Tavern, NY 12575
Phone	
FAX	
Email	

Date Received	2/15/2006
Date Completed	2/17/2006
CHARGES	$150.00

Identification	Lab. No.	As (mg/L)	As(III)/As(V)			
CECW-6I III	06-0181	0.28				
CECW-6I	06-0182	0.34	4.96			
PO-10 III	06-0183	0.089				
PO-10	06-0184	0.10	9.86			
MW-5 III	06-0185	0.001				
MW-5	06-0186	0.004	0.33			
ECW-1I III	06-0187	0.11				
ECW-1I	06-0188	0.16	2.23			
CECW-ID III	06-0189	0.011				
CECW-ID	06-0190	0.021	1.14			
CECW-ID lab dup	06-0190dup	0.021				

Approved By: ____________________

Attachment H
Compliance Well Arsenic Trend Evaluation Data

Mann-Kendall Analysis: CECW-1

Contaminant: Arsenic

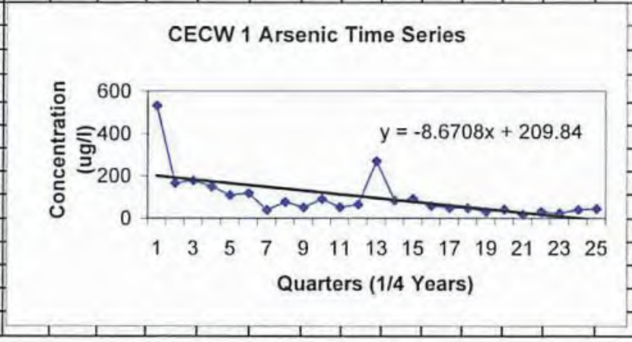
Mann-Kendall "S"	
"S" Value	-187

Variance of "S"	
	Number of tied groups
# 2 times	2
# 3 times	0
# 4 times	1
# 5 times	0
# 6 times	0
# 7 times	0
# 8 times	0
# 9 times	0
# 10 times	0
Variance V(S)	2551

Trend Evaluation	
Z 95%	Sample Z
1.645	-3.721981822
Trend	Decreasing

CECW 1

	Time:Quarters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25				
# Quarters	Concentration	530	165	177	148	107	117	38	75	50	89	51	64	268	83	90	58	48	47	30	41	16	30	23	39	44				Sum
1	530		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-24
2	165			1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-19
3	177				-1	-1	-1	-1	-1	-1	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-20
4	148					-1	-1	-1	-1	-1	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-19
5	107						1	-1	-1	-1	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-16
6	117							-1	-1	-1	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-17
7	38								1	1	1	1	1	1	1	1	1	1	1	-1	1	-1	-1	-1	1	1				10
8	75									-1	1	-1	-1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-9
9	50										1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-2
10	89											-1	-1	1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-11
11	51												1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-4
12	64													1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-7
13	268														-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-12
14	83															1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-9
15	90																-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-10
16	58																	-1	-1	-1	-1	-1	-1	-1	-1	-1				-9
17	48																		-1	-1	-1	-1	-1	-1	-1	-1				-8
18	47																			-1	-1	-1	-1	-1	-1	-1				-7
19	30																				1	-1	0	-1	1	1				1
20	41																					-1	-1	-1	-1	1				-3
21	16																						1	1	1	1				4
22	30																							-1	1	1				1
23	23																								1	1				2
24	39																									1				1
25	44																													



Mann-Kendall "S" -187
(# plus - # minus)

Mann-Kendall Analysis: CECW-2

Contaminant: Arsenic

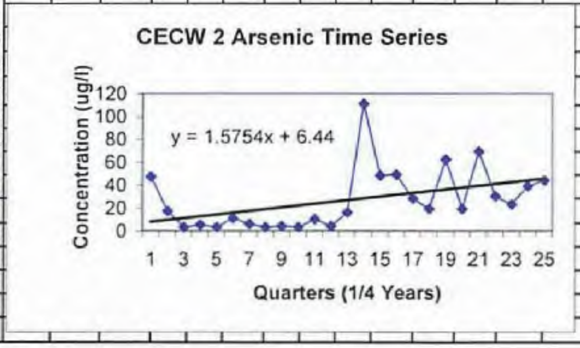
Mann-Kendall "S"	
"S" Value	122

Variance of "S"	
	Number of tied groups
# 2 times	2
# 3 times	0
# 4 times	1
# 5 times	0
# 6 times	0
# 7 times	0
# 8 times	0
# 9 times	0
# 10 times	0
Variance V(S)	2551

Trend Evaluation	
Z 95%	Sample Z
1.645	2.395530853
Trend	Increasing

CECW 2

	Time:Quarters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25				
# Quarters	Concentration	47	17	3	5	3	11	6	3	4	3	10	4	16	111	48	49	28	19	62	19	69	30	23	39	44				Sum
1	47		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	-1	-1	1	-1	1	-1	-1	-1	-1				-14
2	17			-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1				1
3	3				1	0	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				19
4	5					-1	1	1	-1	-1	-1	1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1				11
5	3						1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				18
6	11							-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1				7
7	6								-1	-1	-1	1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1				10
8	3									1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				16
9	4										-1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1				13
10	3											1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				15
11	10												-1	1	1	1	1	1	1	1	1	1	1	1	1	1				12
12	4													1	1	1	1	1	1	1	1	1	1	1	1	1				13
13	16														1	1	1	1	1	1	1	1	1	1	1	1				12
14	111															-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-11
15	48																1	-1	-1	1	-1	1	-1	-1	-1	-1				-4
16	49																	-1	-1	1	-1	1	-1	-1	-1	-1				-5
17	28																		-1	1	-1	1	1	-1	1	1				2
18	19																			1	0	1	1	1	1	1				6
19	62																				-1	1	-1	-1	-1	-1				-4
20	19																					1	1	1	1	1				5
21	69																						-1	-1	-1	-1				-4
22	30																							-1	1	1				1
23	23																								1	1				2
24	39																									1				1
25	44																													



Mann-Kendall "S" (# plus - # minus)	122

Mann-Kendall Analysis: CECW-3

Contaminant: **Arsenic**

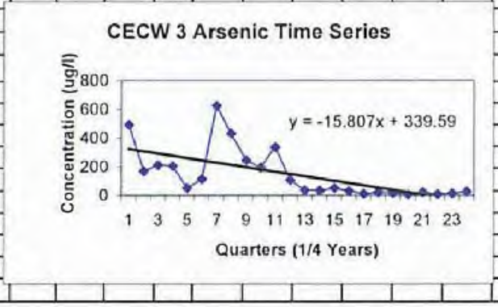
Mann-Kendall "S"	
"S" Value	-177

Variance of "S"	
	Number of tied groups
# 2 times	1
# 3 times	0
# 4 times	0
# 5 times	0
# 6 times	0
# 7 times	0
# 8 times	0
# 9 times	0
# 10 times	0
Variance V(S)	2561

Trend Evaluation	
Z 95%	Sample Z
1.645	-3.517346982
Trend	Decreasing

CECW 3

	Time:Quarters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24					
# Quarters	Concentration	489	167	208	203	48	112	622	428	243	192	334	104	34	31	50	30	10	20	16	5	20	6	12	24					Sum
1	489		-1	-1	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-21
2	167			1	1	-1	-1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-8
3	208				-1	-1	-1	1	1	1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-13
4	203					-1	-1	1	1	1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-12
5	48						1	1	1	1	1	1	1	-1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-3
6	112							1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-8
7	622								-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-17
8	428									-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-16
9	243										-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-13
10	192											1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-12
11	334												-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-13
12	104													-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-12
13	34														-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-9
14	31															1	-1	-1	-1	-1	-1	-1	-1	-1	-1					-8
15	50																-1	-1	-1	-1	-1	-1	-1	-1	-1					-9
16	30																	-1	-1	-1	-1	-1	-1	-1	-1					-8
17	10																		1	1	-1	1	-1	1	1					3
18	20																			-1	-1	0	-1	-1	1					-3
19	16																				-1	1	-1	-1	1					-1
20	5																					1	1	1	1					4
21	20																						-1	-1	1					-1
22	6																							1	1					2
23	12																								1					1
24	24																													0
																														0
																														0
																														0
																														0



Mann-Kendall "S" (# plus - # minus) -177

Mann-Kendall Analysis: CECW-5

Contaminant: Arsenic

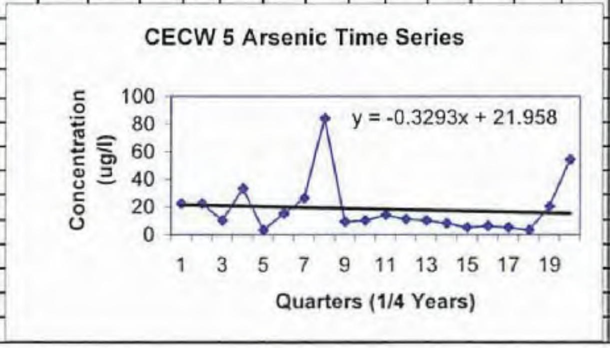
Mann-Kendall "S"	
"S" Value	-52

Variance of "S"	
	Number of tied groups
# 2 times	3
# 3 times	1
# 4 times	1
# 5 times	0
# 6 times	0
# 7 times	0
# 8 times	0
# 9 times	0
# 10 times	0
Variance V(S)	2547

Trend Evaluation	
Z 95%	Sample Z
1.645	-1.050243053
Trend	Stable/No Trend

CECW 5

	Time:Quarters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20									
# Quarters	Concentration	22	22	10	33	3	15	26	84	9	10	14	11	10	8	5	6	5	3	20	54									Sum
1	22		0	-1	1	-1	-1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1									-10
2	22			-1	1	-1	-1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1									-10
3	10				1	-1	1	1	1	-1	0	1	1	0	-1	-1	-1	-1	-1	1	1									1
4	33					-1	-1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1									-12
5	3						1	1	1	1	1	1	1	1	1	1	1	1	0	1	1									14
6	15							1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1									-6
7	26								1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1									-9
8	84									-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1									-12
9	9										1	1	1	1	-1	-1	-1	-1	-1	1	1									1
10	10											1	1	0	-1	-1	-1	-1	-1	1	1									-1
11	14												-1	-1	-1	-1	-1	-1	-1	1	1									-5
12	11													-1	-1	-1	-1	-1	-1	1	1									-4
13	10														-1	-1	-1	-1	-1	1	1									-3
14	8															-1	-1	-1	-1	1	1									-2
15	5																1	0	-1	1	1									2
16	6																	-1	-1	1	1									0
17	5																		-1	1	1									1
18	3																			1	1									2
19	20																				1									1
20	54																													0
																														0
																														0
																														0
																														0
																														0
																														0
																														0
																														0



Mann-Kendall "S" (# plus - # minus): -52

Mann-Kendall Analysis: CECW-6

Contaminant: Arsenic

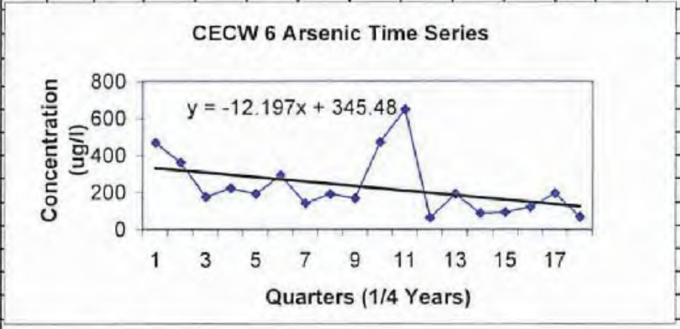
Mann-Kendall "S"	
"S" Value	-55

Variance of "S"	
	Number of tied groups
# 2 times	0
# 3 times	0
# 4 times	0
# 5 times	0
# 6 times	0
# 7 times	0
# 8 times	0
# 9 times	0
# 10 times	0
Variance V(S)	2562

Trend Evaluation	
Z 95%	Sample Z
1.645	-1.106365092
Trend	Stable/No Trend

CECW 6

	Time:Quarters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
# Quarters	Concentration	467	361	175	221	192	292	140	189	167	470	648	62	191	86	91	119	195	67	Sum
1	467		-1	-1	-1	-1	-1	-1	-1	-1	1	1	-1	-1	-1	-1	-1	-1	-1	-13
2	361			-1	-1	-1	-1	-1	-1	-1	1	1	-1	-1	-1	-1	-1	-1	-1	-12
3	175				1	1	1	-1	1	-1	1	1	-1	1	-1	-1	-1	1	-1	1
4	221					-1	1	-1	-1	-1	1	1	-1	-1	-1	-1	-1	-1	-1	-8
5	192						1	-1	-1	-1	1	1	-1	-1	-1	-1	-1	1	-1	-5
6	292							-1	-1	-1	1	1	-1	-1	-1	-1	-1	-1	-1	-8
7	140								1	1	1	1	-1	1	-1	-1	-1	1	-1	1
8	189									-1	1	1	-1	1	-1	-1	-1	1	-1	-2
9	167										1	1	-1	1	-1	-1	-1	1	-1	-1
10	470											1	-1	-1	-1	-1	-1	-1	-1	-6
11	648												-1	-1	-1	-1	-1	-1	-1	-7
12	62													1	1	1	1	1	1	6
13	191														-1	-1	-1	1	-1	-3
14	86															1	1	1	-1	2
15	91																1	1	-1	1
16	119																	1	-1	0
17	195																		-1	-1
18	67																			



Mann-Kendall "S" (# plus - # minus) -55

Mann-Kendall Analysis: MW-5

Contaminant: **Arsenic**

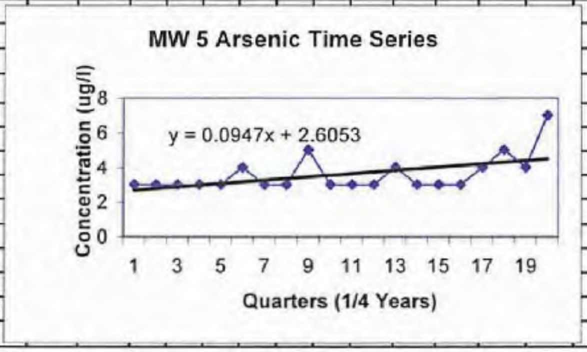
Mann-Kendall "S"	
"S" Value	63

Variance of "S"	
	Number of tied groups
# 2 times	1
# 3 times	0
# 4 times	1
# 5 times	0
# 6 times	0
# 7 times	0
# 8 times	0
# 9 times	0
# 10 times	1
Variance V(S)	2427

Trend Evaluation	
Z 95%	Sample Z
1.645	1.258423963
Trend	**Stable/No Trend**

MW 5

	Time:Quarters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20									
# Quarters	Concentration	3	3	3	3	3	4	3	3	5	3	3	3	4	3	3	3	4	5	4	7									Sum
1	3		0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	1	1	1									7
2	3			0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	1	1	1									7
3	3				0	0	1	0	0	1	0	0	0	1	0	0	0	1	1	1	1									7
4	3					0	1	0	0	1	0	0	0	1	0	0	0	1	1	1	1									7
5	3						1	0	0	1	0	0	0	1	0	0	0	1	1	1	1									7
6	4							-1	-1	1	-1	-1	-1	0	-1	-1	-1	0	1	0	1									-5
7	3								0	1	0	0	0	1	0	0	0	1	1	1	1									6
8	3									1	0	0	0	1	0	0	0	1	1	1	1									6
9	5										-1	-1	-1	-1	-1	-1	-1	-1	0	-1	1									-8
10	3											0	0	1	0	0	0	1	1	1	1									5
11	3												0	1	0	0	0	1	1	1	1									5
12	3													1	0	0	0	1	1	1	1									5
13	4														-1	-1	-1	0	1	0	1									-1
14	3															0	0	1	1	1	1									4
15	3																0	1	1	1	1									4
16	3																	1	1	1	1									4
17	4																		1	0	1									2
18	5																			-1	1									0
19	4																				1									1
20	7																													0
																														0
																														0
																														0
																														0
																														0
																														0
																														0



Mann-Kendall "S" (# plus - # minus)	63

Mann-Kendall Analysis: _PO-8

Contaminant: Arsenic

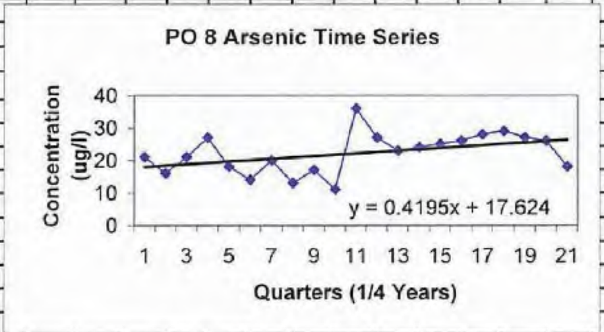
Mann-Kendall "S"	
"S" Value	62

Variance of "S"	
	Number of tied groups
# 2 times	3
# 3 times	1
# 4 times	0
# 5 times	0
# 6 times	0
# 7 times	0
# 8 times	0
# 9 times	0
# 10 times	0
Variance V(S)	2555

Trend Evaluation	
Z 95%	Sample Z
1.645	1.206718733
Trend	Stable/No Trend

PO 8

	Time:Quarters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21								
# Quarters	Concentration	21	16	21	27	18	14	20	13	17	11	36	27	23	24	25	26	28	29	27	26	18								Sum
1	21		-1	0	1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	-1								3
2	16			1	1	1	-1	1	-1	1	-1	1	1	1	1	1	1	1	1	1	1	1								13
3	21				1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	-1								4
4	27					-1	-1	-1	-1	-1	-1	1	0	-1	-1	-1	-1	1	1	0	-1	-1								-9
5	18						-1	1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	0								7
6	14							1	-1	1	-1	1	1	1	1	1	1	1	1	1	1	1								11
7	20								-1	-1	-1	1	1	1	1	1	1	1	1	1	1	-1								6
8	13									1	-1	1	1	1	1	1	1	1	1	1	1	1								11
9	17										-1	1	1	1	1	1	1	1	1	1	1	1								10
10	11											1	1	1	1	1	1	1	1	1	1	1								11
11	36												-1	-1	-1	-1	-1	-1	-1	-1	-1	-1								-10
12	27													-1	-1	-1	-1	1	1	0	-1	-1								-4
13	23														1	1	1	1	1	1	1	-1								6
14	24															1	1	1	1	1	1	-1								5
15	25																1	1	1	1	1	-1								4
16	26																	1	1	1	0	-1								2
17	28																		1	-1	-1	-1								-2
18	29																			-1	-1	-1								-3
19	27																				-1	-1								-2
20	26																					-1								-1
21	18																													0
																														0
																														0
																														0
																														0
																														0
																														0



Mann-Kendall "S" (# plus - # minus) 62

Mann-Kendall Analysis: PO-9

Contaminant: **Arsenic**

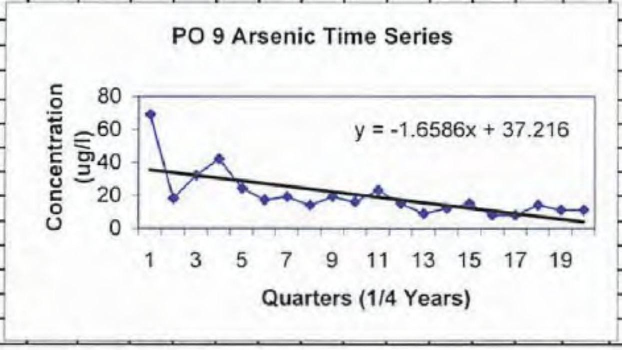
Mann-Kendall "S"	
"S" Value	-123

Variance of "S"	
	Number of tied groups
# 2 times	5
# 3 times	0
# 4 times	0
# 5 times	0
# 6 times	0
# 7 times	0
# 8 times	0
# 9 times	0
# 10 times	0
Variance V(S)	2557

Trend Evaluation	
Z 95%	Sample Z
1.645	-2.452202445
Trend	**Decreasing**

PO 9

	Time:Quarters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20									
# Quarters	Concentration	69	18	32	42	24	17	19	14	19	16	23	15	9	12	15	8	8	14	11	11									Sum
1	69		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1									-19
2	18			1	1	1	-1	1	-1	1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1									-6
3	32				1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1									-15
4	42					-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1									-16
5	24						-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1									-15
6	17							1	-1	1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1									-8
7	19								-1	0	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1									-10
8	14									1	1	1	1	-1	-1	1	-1	-1	0	-1	-1									-1
9	19										-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1									-9
10	16											1	-1	-1	-1	-1	-1	-1	-1	-1	-1									-8
11	23												-1	-1	-1	-1	-1	-1	-1	-1	-1									-9
12	15													-1	-1	0	-1	-1	-1	-1	-1									-7
13	9														1	1	-1	-1	1	1	1									3
14	12															1	-1	-1	1	-1	-1									-2
15	15																-1	-1	-1	-1	-1									-5
16	8																	0	1	1	1									3
17	8																		1	1	1									3
18	14																			-1	-1									-2
19	11																				0									0
20	11																													0
																														0
																														0
																														0
																														0
																														0
																														0
																														0



Mann-Kendall "S" -123
(# plus - # minus)

Mann-Kendall Analysis: PO-10

Contaminant: Arsenic

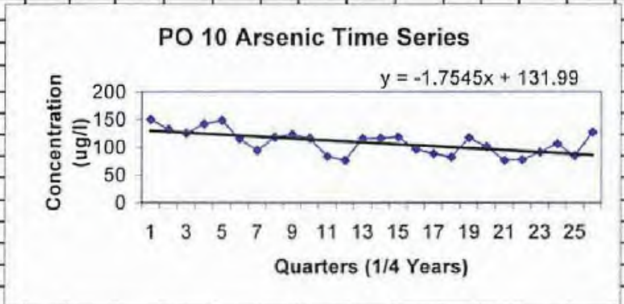
Mann-Kendall "S"	
"S" Value	-135

Variance of "S"	
	Number of tied groups
# 2 times	4
# 3 times	0
# 4 times	0
# 5 times	0
# 6 times	0
# 7 times	0
# 8 times	0
# 9 times	0
# 10 times	0
Variance V(S)	2558

Trend Evaluation	
Z 95%	Sample Z
1.645	-2.688986602
Trend	Decreasing

PO 10

	Time:Quarters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26			
# Quarters	Concentration	150	132	125	142	148	115	94	118	123	116	83	76	115	116	118	96	88	82	117	101	76	77	91	106	84	127			Sum
1	150		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1			-25
2	132			-1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1			-20
3	125				1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1			-17
4	142					1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1			-20
5	148						-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1			-21
6	115							-1	1	1	1	-1	-1	0	1	1	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	1			-5
7	94								1	1	1	-1	-1	1	1	1	1	-1	-1	1	1	-1	-1	-1	1	-1	1			3
8	118									1	-1	-1	-1	-1	-1	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1			-13
9	123										-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1			-15
10	116											-1	-1	-1	0	1	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	1			-9
11	83												-1	1	1	1	1	1	-1	1	1	-1	-1	1	1	1	1			7
12	76													1	1	1	1	1	1	1	1	0	1	1	1	1	1			13
13	115														1	1	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	1			-5
14	116															1	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	1			-6
15	118																-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1			-9
16	96																	-1	-1	1	1	-1	-1	-1	1	-1	1			-2
17	88																		-1	1	1	-1	-1	1	1	-1	1			1
18	82																			1	1	-1	-1	1	1	1	1			4
19	117																				-1	-1	-1	-1	-1	-1	1			-5
20	101																					-1	-1	-1	1	-1	1			-2
21	76																						1	1	1	1	1			5
22	77																							1	1	1	1			4
23	91																								1	-1	1			1
24	106																									-1	1			0
25	84																										1			1
26	127																													0
																														0


PO 10 Arsenic Time Series

Mann-Kendall "S" (# plus - # minus)	-135

APPENDIX C

NMBGMR ANALYTICAL RESULTS REPORT

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES
NEW MEXICO TECH
801 LEROY PLACE, SOCORRO, NM 87801
PH: 505-835-5160 FAX: 505-835-6333

ARSENIC AND IRON ANALYSES - Dominion pore waters

Customer name	Greg Miller
Company	AMEC
Address	P.O. Box 445
City, State, Zip	Socorro NM 87801
Phone	(575) 835-2569
FAX	(575) 835-2609
Cell phone	
Email	greg.miller@amec.com

Date Received 2/16/2010
Date Completed 2/25/2010

Lab ID	Customer ID	Dilution (As)	Arsenic (mg/L)	Iron (mg/L)
Detection limits *			0.00008	0.002
Reporting limits*			0.001	0.01
10-0074	7A 11-13	1:20	0.086	0.039
10-0075	4B 48-50	1:20	0.049	0.042
10-0076	1C 30-33	1:20	0.038	0.96
10-0077	2A 9-12	1:10	0.45	0.018
10-0078	6B 0-3	1:10	0.20	1.2
10-0079	1C 6-9	1:10	0.039	0.004
10-0080	3C 10-12	1:10	0.037	0.033
10-0080 dup	3C 10-12	1:10	0.037	0.027
10-0081	7A 7-9	1:10	0.20	0.061
10-0082	4A 23-24	1:10	0.032	0.48
10-0083	3C 24-27	1:10	0.036	ND
10-0084	6B 23-25	1:20	0.031	0.49
10-0085	4B 19-21	1:10	0.029	ND
10-0086	4A 13-14	1:10	0.059	ND
10-0087	2A 43-46	1:20	0.10	0.008
10-0088	7A 13-16	1:20	0.068	0.005
10-0089	6B 12-14	1:10	0.028	2.0
10-0090	2C 14-16	1:20	0.039	0.14
10-0090 dup	2C 14-16	1:20	0.039	0.21
10-0091	4C 0-3	1:10	0.038	0.074
10-0092	4A 30-33	1:10	0.036	4.3
10-0093	7A top-2	1:10	0.22	10
10-0094	1A 24-27	1:10	0.037	0.007
10-0095	6A 10-12	1:20	0.044	19
10-0096	2B 28-32	1:10	0.054	0.081
10-0097	2C 28-32	1:10	0.034	13
10-0098	6B 30-32	1:20	0.032	0.81
10-0099	2B 10-14	1:10	0.15	0.034
10-0100	1B 49-53	1:10	0.18	0.012
10-0100 dup	1B 49-53	1:10	0.18	0.010
10-0101	1A 30-40	1:10	0.041	ND
10-0102	1B 40-43	1:10	0.034	ND
10-0103	1A top-2	1:10	0.041	0.085
10-0104	4C 30-34	1:10	0.016	4.2
10-0105	2C 43-46	1:20	0.036	0.58
10-0106	2B 40-43	1:20	0.033	0.004
10-0107	6A top-2	1:10	0.023	1.5
10-0108	1B 6-9	1:10	0.050	0.007
10-0109	1A 12-15	1:10	0.024	0.011
10-0109 dup	1A 12-15	1:10	0.022	ND
10-0110	2C 43-46	1:20	0.053	5.3
10-0111	2B top-4	1:10	0.17	0.012

' All iron measurements were made at 1:20 dilution.
*** For each dilution, reporting limits increase by a factor equaling the dilution factor. For example, a normal reporting limit of 0.01 becomes 0.2 with a 1:20 dilution.**

Approved by:

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES
NEW MEXICO TECH
801 LEROY PLACE, SOCORRO, NM 87801
PH: 505-835-5160 FAX: 505-835-6333

ARSENIC AND IRON ANALYSES - Microwave extract, Dominion sediments

Customer name	Gregory Miller
Company	AMEC
Address	P.O. Box 445
City, State, Zip	Socorro NM 87801
Phone	(505) 835-2569
FAX	(505) 835-2609
Cell phone	
Email	greg.miller@amec.com

Date Received 2/16/2010
Date Completed 3/10/2010

Lab sample ID	Customer ID	Arsenic (mg/kg)	Iron (mg/kg)
Detection limits		0.00008	0.002
Reporting limits		0.001	0.01
10-0074	7A 11-13	8.2	2707
10-0075	4B 48-50	4.9	32838
10-0076	1C 30-33	1.3	3362
10-0077	2A 9-12	1.2	1116
10-0078	6B 0-3	1.7	3144
10-0079	1C 6-9	0.3	1039
10-0080	3C 10-12	7.9	38166
10-0080 dup	3C 10-12	8.1	38762
10-0081	7A 7-9	17.2	4626
10-0082	4A 23-24	0.7	3513
10-0083	3C 24-27	6.2	31072
10-0084 1	6B 23-25	3.4	5988
10-0084 2	6B 23-25	4.5	6487
10-0084 3	6B 23-25	2.5	5378
10-0085	4B 19-21	7.0	41161
10-0086	4A 13-14	0.3	2135
10-0087	2A 43-46	1.0	2172
10-0088	7A 13-16	6.9	3074
10-0089 1	6B 12-14	3.4	4181
10-0089 2	6B 12-14	5.5	8276
10-0089 3	6B 12-14	3.3	6483
10-0090	2C 14-16	1.0	2852
10-0090 dup	2C 14-16	1.0	3128
10-0091	4C 0-3	5.0	22611
10-0092	4A 30-33	1.6	6941
10-0093	7A TOP-2	19.9	4558
10-0094	1A 24-27	0.5	1164
10-0095 1	6A 10-12	4.8	5927
10-0095 2	6A 10-12	6.5	7991
10-0095 3	6A 10-12	3.1	5061
10-0096	2B 28-32	0.6	1091
10-0097	2C 28-32	0.5	1612
10-0098 1	6B 30-32	5.0	6102
10-0098 2	6B 30-32	7.2	9273
10-0098 3	6B 30-32	2.2	6225
10-0099	2B 10-14	0.8	1214
10-0100	1B 49-53	0.6	2673
10-0100 dup	1B 49-53	0.9	3951

Lab sample ID	Customer ID	Arsenic (mg/kg)	Iron (mg/kg)
Detection limits		0.00008	0.002
Reporting limits		0.001	0.01
10-0101	1A 30-40	1.1	2161
10-0102	1B 40-43	4.2	11227
10-0103	1A TOP-2	0.8	1713
10-0104	4C 30-34	4.2	24728
10-0105	2C 43-46	5.2	4834
10-0106	2B 40-43	1.5	2643
10-0107	6A TOP-2	4.9	4357
10-0108	1B 6-9	8.2	37176
10-0109	1A 12-15	0.3	1224
10-0110 1	2C 43-46	9.3	6202
10-0110 1dup	2C 43-46	7.9	5222
10-0110 2	2C 43-46	20	10490
10-0110 3	2C 43-46	1.4	3621
10-0111	2B TOP-4	1.5	3129
lksd3 r1		22	33857
lksd3 r3		23	34063
lksd3 r5		24	35476
Published LKSD-3		23	35000

Lake Sediment Standard -- National Resources Canada reference:
http://www.nrcan.gc.ca/mms-smm/tect-tech/ccrmp/cer-cer/lksd-1-eng.htm

To estimate how close a sample measurement is to the instrument detection limit or reporting limit, multiply the reported value (mg/kg) by 0.0005, which is the approximate weight of sample used (0.5 g) divided by the final extract volume (50 mL) and dilution factor (20).

Approved by:

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES
NEW MEXICO TECH
801 LEROY PLACE, SOCORRO, NM 87801
Phone: 505-835-5160 Fax: 505-835-6333

Quality control samples for Dominion pore water sample analysis, arsenic analysis

Method detection limit (mg/L) determined 2/24/10	0.00003
Method reporting limit (mg/L)	0.001

Calibration check objective, percent yield 90-110%

Arsenic	Expected or published (mg/L)	Percent yield (%)
Calibration check (2/24/10)	0.050	102
Calibration check (2/24/10)	0.050	102
Calibration check (2/24/10)	0.050	102
Calibration check (2/24/10)	0.050	101
Calibration check (2/24/10)	0.050	100
Calibration check (2/24/10)	0.050	99
Calibration check (2/24/10)	0.050	103
Calibration check (2/24/10)	0.050	103
Calibration check (2/24/10)	0.050	102
Calibration check (2/24/10)	0.050	103
USGS standard T-179	1.90	100
USGS standard T-179	1.90	104

Blank objective, below reporting limit

Arsenic	Result (mg/L)
Blank (2/24/10)	0.000041
Blank (2/24/10)	BDL
Blank (2/24/10)	BDL
Blank (2/24/10)	BDL
Blank (2/24/10)	BDL
Blank (2/24/10)	BDL
Blank (2/24/10)	BDL
Blank (2/24/10)	BDL
Blank (2/24/10)	BDL
Blank (2/24/10)	BDL

Blank spike objective, percent recovery 90-100%

Arsenic	Expected (mg/L)	Percent recovery (%)
BlkSpk3	0.003	102
BlkSpk4	0.004	108
BlkSpk2	0.002	110
BlkSpk20	0.020	110

Matrix spike objective, percent recovery 80% of 120%

Sample ID	Customer sample ID	Arsenic spike amount (mg/L)	Average conc. of diluted sample (mg/L)	Spiked sample (mg/L)	Percent recovery
10-0080	3C 10-12	0.004	0.0037	0.0081	109
10-0090	2C 14-16	0.002	0.0020	0.0041	107
10-0100	1B 49-53	0.020	0.0180	0.0403	112
10-0109	1A 12-15	0.003	0.0023	0.0051	96

Dilution duplicate objective, relative percent difference ±10%

Sample ID	Customer sample ID	Average arsenic (mg/kg)	Relative % difference of duplicates
10-0080	3C 10-12	0.037	-0.03
10-0090	2C 14-16	0.039	0.33
10-0100	1B 49-53	0.18	0.67
10-0109	1A 12-15	0.023	8.8

Approved by:

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES
NEW MEXICO TECH
801 LEROY PLACE, SOCORRO, NM 87801
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Quality control samples for Dominion microwave extract sample analysis, arsenic analysis

Method detection limit (mg/L) determined 2/24/10	0.00003
Method reporting limit (mg/L)	0.001

Calibration check objective, percent yield 90-110%

Arsenic	Expected or published (mg/L)	Percent yield (%)
Calibration check (3/8/10)	0.050	97
Calibration check (3/8/10)	0.050	97
Calibration check (3/9/10)	0.050	96
Calibration check (3/9/10)	0.050	96
Calibration check (3/9/10)	0.050	96
Calibration check (3/9/10)	0.050	96
Calibration check (3/9/10)	0.050	98
Calibration check (3/9/10)	0.050	96
Calibration check (3/9/10)	0.050	96
Calibration check (3/9/10)	0.050	96
USGS standard T-179	0.0019	102
USGS standard T-179	0.0019	97

Blank objective, below reporting limit

Arsenic	Result (mg/L)
Method blank (3/8/10)	0.00004
Method blank (3/8/10)	BDL
Method blank (3/9/10)	BDL
Method blank (3/9/10)	BDL
Method blank (3/9/10)	BDL
Method blank (3/9/10)	BDL
Method blank (3/9/10)	BDL
Method blank (3/9/10)	BDL
Method blank (3/9/10)	BDL

Microwave duplicates

Sample ID	Average arsenic (mg/kg)	Relative % difference of duplicates
10-0080	8.0	-2.3
10-0090	1.0	-1.1
10-0100	0.7	-28
10-0110 1	8.6	15

Standard reference material and microwave blanks. *

Sample ID	Measurement (mg/L)	Arsenic (mg/kg)	Published (mg/kg)	Percent yield
lksd3 r1	0.22	22	23	96
lksd3 r3	0.23	23	23	99
lksd3 r5	0.23	24	23	103
blank r1	0.0005			
blank r3	0.002			
blank r4	BDL			
blank r5	BDL			
blank r6	0.0008			
blank r7	BDL			

Lake Sediment Standard -- National Resources Canada reference:
http://www.nrcan.gc.ca/mms-smm/tect-tech/ccrmp/cer-cer/lksd-1-eng.htm
*Microwave blanks were diluted 1:20 and should be compared to a reporting limit times 20.

Approved by: ____________________

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES
NEW MEXICO TECH
801 LEROY PLACE, SOCORRO, NM 87801
Phone: 505-835-5160 Fax: 505-835-6333

Quality control samples for Dominion pore water sample analysis, iron analysis

Method detection limit (mg/L)	0.0020
Method reporting limit (mg/L)	0.01

Calibration check objective, percent yield 90-110%

Iron	Expected or published (mg/L)	Percent yield (%)
Calibration check (2/25/10)	10	102
Calibration check (2/25/10)	10	104
Calibration check (2/25/10)	10	101
Calibration check (2/25/10)	10	102
Calibration check (2/25/10)	10	101
Calibration check (2/25/10)	10	102
Calibration check (2/25/10)	10	103
USGS standard T-135	0.228	102
USGS standard T-135	0.228	102

Blank objective, below reporting limit

Iron	Result (mg/L)
Blank (2/25/10)	BDL
Blank (2/25/10)	BDL
Blank (2/25/10)	BDL
Blank (2/25/10)	BDL
Blank (2/25/10)	BDL
Blank (2/25/10)	BDL
Blank (2/25/10)	BDL

Blank spike objective, percent recovery 90-100%

Iron	Expected (mg/L)	Percent recovery (%)
BlkSpk0.01	0.010	99

Matrix spike objective, percent recovery 80% of 120%

Sample ID	Customer sample ID	Iron spike amount (mg/L)	Average conc. of diluted sample (mg/L)	Spiked sample (mg/L)	Percent recovery (%)
10-0080	3C 10-12	0.010	BDL	0.013	110
10-0090	2C 14-16	0.010	0.012	0.021	86
10-0091	4C 0-3	0.010	0.003	0.013	101
10-0100	1B 49-53	0.010	BDL	0.011	101
10-0109	1A 12-15	0.010	BDL	0.010	98

Dilution duplicate objective, relative percent difference ±10%

Sample ID	Customer sample ID	Dilution factor	Average iron (mg/kg)	Relative % difference of duplicates
10-0080	3C 10-12	1:20	0.030	21
10-0090	2C 14-16	1:20	0.24	24
10-0091	4C 0-3	1:20	0.065	28
10-0100	1B 49-53	1:20	0.011	12
10-0109	1A 12-15	1:20	BDL	>100
10-0078 *	6B 0-3	1:20 and 1:40	1.2	-3.4
10-0089 *	6B 12-14	1:20 and 1:40	2.0	-3.2
10-0095 *	6A 10-12	1:20 and 1:40	19	0.02
10-0105 *	2C 43-46	1:20 and 1:40	0.58	-1.2

* Duplicates for these samples were reanalyzed on 4/9/10 to demonstrate the analytical precision on samples with iron concentrations well above the reporting limit. Each sample was diluted 1:20 and 1:40 for the reanalysis. These two dilutions were compared in the relative % difference.

Approved by: ______________________

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Quality control samples for Dominion microwave extract sample analysis, iron analysis

Method detection limit (mg/L)	0.0020
Method reporting limit (mg/L)	0.01

Calibration check objective, percent yield 90-110%

Iron	Expected or published (mg/L)	Percent yield (%)
Calibration check (3/5/10)	10	103
Calibration check (3/5/10)	10	103
Calibration check (3/5/10)	10	103
Calibration check (3/5/10)	10	103
Calibration check (3/5/10)	10	104
Calibration check (3/5/10)	10	101
Calibration check (3/5/10)	10	101
Calibration check (3/5/10)	10	101
Calibration check (3/8/10)	10	102
Calibration check (3/8/10)	10	102
Calibration check (3/8/10)	10	101
Calibration check (3/10/10)	10	99
Calibration check (3/10/10)	10	100
USGS standard T-135	0.228	104
USGS standard T-135	0.228	104
USGS standard T-135	0.228	102
USGS standard T-135	0.228	100
USGS standard T-201	1.8	101
USGS standard T-201	1.8	97
USGS standard T-201	1.8	100

Blank objective, below reporting limit

Iron	Result (mg/L)
Method blank (3/5/10)	BDL
Method blank (3/5/10)	BDL
Method blank (3/5/10)	0.0026
Method blank (3/5/10)	BDL
Method blank (3/5/10)	BDL
Method blank (3/5/10)	BDL
Method blank (3/5/10)	BDL
Method blank (3/5/10)	BDL
Method blank (3/8/10)	0.0023
Method blank (3/8/10)	BDL
Method blank (3/8/10)	BDL
Method blank (3/10/10)	BDL
Method blank (3/10/10)	BDL

Microwave duplicates

Sample ID	Average iro n (mg/kg)	Relative % difference
10-0080	38464	-1.5
10-0090	2990	-9.2
10-0100	3312	-39
10-0110 1	5712	17

Standard reference material and microwave blanks. *

Sample ID	Measurement (mg/L)	Iron (mg/kg)	Published (mg/kg)	Percent yield
lksd3 r1	337	33857	35000	97
lksd3 r3	338	34063	35000	97
lksd3 r5	352	35476	35000	101
blank r1	BDL			
blank r3	0.016			
blank r4	BDL			
blank r5	BDL			
blank r6	BDL			
blank r7	0.068			

Lake Sediment Standard – National Resources Canada reference:
http://www.nrcan.gc.ca/mms-smm/tect-tech/ccmp/cer-cer/lksd-1-eng.htm

*Microwave blanks were diluted 1:20 and should be compared to the reporting limit times 20.

Approved by: ____________________

APPENDIX D

PHASE SEPARATION SCIENCE, INC. ANALYTICAL RESULTS REPORT