1.0 INTRODUCTION

The Battlefield Golf Club (the 'Site') is an 18-hole golf course located southeast of the intersection of Whittamore Road and Centerville Turnpike South in Chesapeake, Virginia (see Figures 1 and 2). Approximately 1.5 million tons of fly ash (Type F Coal Combustion By-Products [CCB]) generated from coal-fired power generating units at the Chesapeake Energy Center (CEC) was provided for beneficial use in structural fill subsoil (amended ash) during construction of the golf course from approximately April 2002 through March 2007. Fly ash amendments were specified to include approximately 2 percent of alkaline admixtures, including; Lime Kiln Dust or Portland Cement and Cement Kiln Dust. The amended ash was specified to be capped with a minimum 18 inches of soil cover. Several man-made ponds were excavated at the Site during construction of the golf course to produce soil used for cover of the amended ash.

MACTEC Engineering and Consulting, Inc. (MACTEC) performed field activities for a Post-Construction Ash Fill, Soil Cover and Groundwater Evaluation at the Site in November and December 2008 (Phase I) and June 2009 (Phase II). The following report presents the results from both phases of Post-Construction Evaluation performed by MACTEC.

2.0 BACKGROUND

URS Corporation (URS) performed a Hydrologic Investigation, dated September 21, 2001, prior to placement of ash at the Site. This Hydrologic Investigation included the advancement of seven soil borings and installation of five groundwater monitoring wells, along with geotechnical analysis of soil and chemical analysis (primarily metals) of soil and groundwater at the site. Twelve previous soil borings were reportedly advanced at the site to an approximate depth of 25.5 feet below grade by McCallum Testing Laboratories, Inc. to evaluate subsurface physical properties in March 2001. According to the URS Hydrologic Investigation, groundwater was encountered during drilling beneath a 'shallow clayey layer', at an approximate depth of 5 to 6 feet below grade at the time of drilling in July 2001. According to Table 2 of the URS Hydrologic Investigation, water levels in monitoring wells ranged from 1.93 to 4.63 feet below grade on August 1, 2001. Monitoring wells installed by URS were reportedly screened within greenish-gray medium to fine sand of the Columbia Group and finer-grained sandy silt with some clay of the upper Yorktown Formation was encountered in soil borings from approximately 43 to 50 feet below grade. One of the five monitoring wells installed by URS remains at the Site (identified within this report as MW-URS-2).

Well construction information for 17 supply wells in the vicinity of the site were summarized in Table 4 (Local Water Supply Summary) of the URS Hydrologic Investigation. The top of the screen depths for these wells reportedly range from 15 to 107 feet below grade and total depths range from 32 to 130 feet below grade. MACTEC has not performed a detailed evaluation of residential well data, but for the purpose of this report, there appear to be residential wells screened in both the Columbia Group and Yorktown Formations.

In May 2008, Kimley-Horn and Associates, Inc (Kimley-Horn) installed three shallow monitoring wells (referred to in this report as MW-KH-1, -2 and -3) within the golf course (in the vicinity of the 7th and 14th fairways). The approximate locations of four existing monitoring wells (one installed by URS and three installed by Kimley-Horn) are indicated on Figure 2. Kimley-Horn collected groundwater samples from the wells installed during their investigation on two occasions and the results of those sampling events reportedly indicated elevated total metals concentrations. However, total suspended solids (TSS) results for these samples exceeded 2,000 milligrams per liter (mg/L), suggesting that these samples were turbid (may have contained sediment). As metals are naturally occurring in soil, groundwater samples that contain sediment or ash may produce metals results that are not representative of actual groundwater conditions.

The primary objective of the field activities discussed in this report is to provide an evaluation of flow characteristics and metals concentrations in surface water and groundwater near the perimeter (within a Dominion easement) and in the interior of the Site. A secondary objective is to evaluate geotechnical properties and amending reagent content of the ash fill, including approximate soil cover thickness.

2.1 MACTEC Post-Construction Evaluation

MACTEC prepared a Sampling and Analysis Plan (SAP) for Dominion, dated November 7, 2008, with the primary objective to provide an assessment of flow characteristics and metals concentrations in surface water and groundwater at the Site (within a Dominion easement) and in the interior of the site (using existing wells, if suitable, and surface water bodies within and along the perimeter of the active golf course). A secondary objective was to evaluate geotechnical properties and amending reagent content of the ash fill, including soil cover thickness (see Appendix C). The field activities associated with this scope of work (SOW) were completed by MACTEC from November 17 through December 10, 2008 (Phase I).

Based on the results of Phase I, MACTEC prepared a second SAP for Dominion, dated May 26, 2009, with the primary objective to further evaluate surface water and groundwater conditions within the southwest quadrant of the Site using existing wells, proposed monitoring wells, soil borings, and surface water bodies (see Appendix F). The field activities associated with this SOW were completed by MACTEC from May 27 through June 18, 2009 (Phase II).

3.0 PHYSICAL SETTING

3.1 Site Location

The Site is located approximately one mile west of the U.S. Naval Reservation - Fentress Landing Field in a generally rural area of Chesapeake, Virginia. The area is generally surrounded by agricultural fields with residential development on adjacent properties to the south and east and light commercial development to the west across Centerville Turnpike South. Figure 1 is a Topographic Map that indicates the general location of the Site (Terraserver-USGS, 1969).

3.2 Topography

The surrounding area is generally flat (see Figure 1), but the Site has been reworked with the addition of the ash fill to have a rolling topography with a general slope to the east-southeast. The Site has been extensively landscaped with various grass types to support golf course use (there are currently few if any trees on the Site). There are drainage ditches along the south and west boundaries of the Site (a drainage ditch also runs along the north side of Whittamore Road, which borders the Site to the north). Surface elevations at the Site range from approximately 7 feet above mean sea level (msl) along the boundary drainage ditch near the southeast corner of the Site to approximately 35 feet msl at the top of the highest hill near the northwest corner of the Site.

3.3 Surface Water Flow

Surface runoff follows topography by overland flow to ponds within the interior of the Site or ditches along the borders of the Site. The ditch along the western boundary of the Site receives surface water from three subsurface culvert pipes that drain from off-site areas west of Centerville Turnpike South (see Figure 3). The west boundary ditch flows south into the easterly flowing south boundary ditch (see Figure 3). The south boundary ditch also receives flow from four ditches that drain the residential area to the south of the Site. The south boundary ditch flows into a series of other drainage ditches that drain into the Pocaty Creek approximately three miles southeast of the Site.

3.4 Regional Geology/Hydrogeology

The Site is located in the Coastal Plain Physiographic Province of eastern Virginia (Calver, 1973). The Coastal Plain consists of an eastward thickening wedge of unconsolidated sediments of gravel, sand, silt, and clay from the Cretaceous to Quaternary periods. Two primary stratigraphic units have been identified as present at or beneath the Site; the Columbia Group and Yorktown Formation (URS, 2001). The Columbia Group generally consists of non-marine (fluvial-deltaic) oxidized clays, silts, sands and gravels that contrast with the underlying marine formations. The Yorktown Formation generally consists of light gray, gray and bluish-gray sands with shell fragments, interbedded silts, clays and bioclastic beds. South of the James River, in the Chesapeake area, glauconitic sands and clayey sands may be present.

Groundwater is generally present within the unconsolidated sediments, often in a subdued reflection of the surface topography. Groundwater flow patterns for the unconfined, uppermost-saturated layer (water table aquifer) typically follow surface-water drainage. However, local flow patterns can be affected by the heterogeneous nature of the unconsolidated fluvial-deltaic sediments. Groundwater may become perched on lenses within the unconsolidated sediments.

4.0 INVESTIGATION ACTIVITIES

MACTEC prepared two SAPs for the Site, dated November 7, 2008 (Phase I) and May 26, 2009 (Phase II) for post-construction field investigation activities. Fishburne Drilling, Inc., (Fishburne) located in Chesapeake, Virginia performed advancement of soil borings, installation of monitoring wells and excavation of test pits at the Site. Soil boring and monitoring well installation activities were performed under the direction of a MACTEC geologist. Test pit excavation oversight and compaction testing were performed by a qualified MACTEC engineer. In general, MACTEC also performed the following Site activities; monitoring well development, gauging and sampling, surface water gauging and sampling, and pond depth gauging and sediment sampling. TestAmerica Laboratories, Inc., located in Nashville, Tennessee (Test America) provided chemical analytical services for this project. EMSL Analytical, Inc., located in Westmont, New Jersey (EMSL) provided particle identification analyses of reference fly ash and kiln dust samples (provided by Dominion from Chesapeake Energy Center and Chemstone, respectively) and amended ash samples collected from the Site. Virginia Tech Soil Genesis and Mine Reclamation – Department of Crop and Soil Environmental Services provided Potential Peroxide Acidity testing of soil samples collected during this investigation. Site Improvement Associates, Inc., (SIA) located in Chesapeake, Virginia performed surveying services at the Site. Field sampling activities were performed in general accordance with the prepared SAPs.

In general, Phase I included the following field activities performed at the Site:

- Development and Sampling of 4 Existing Groundwater Monitoring Wells (MW-KH-1 through -3 and MW-URS-2)

- Installation and Development of 16 Groundwater Monitoring Wells (MW-BGC-5A and -5B through -12A and -12B)

- Installation of 19 Surface Water Staff Gauges (SG-1 through -19), Surveying of Staff Gauges and Monitoring Wells, Gauging, Slug Testing, Surface Water and Groundwater Sampling

- Advancement of 3 Soil Borings (SB-1 through -3), 3 Test Pits (TP-1 through -3) and 33 Hand Auger Borings (A4 through H13)

In general, Phase II included the following field activities performed within the southwest quadrant of the Site:

- Installation and Development of 3 Groundwater Monitoring Wells (MW-BGC-13 through -15)

- Surveying of new Monitoring Wells, Gauging, Slug Testing, Surface Water and Groundwater Sampling

- Advancement of 11 Soil Borings (SB-4 through -14), Road Bed and Stockpile Soil Sampling

- Pond Depth Gauging and Sediment Sampling

Field reports for both phases of the investigation at are included in Appendix A. Boring Logs and Well Completion Diagrams are included in Appendix D. Laboratory analytical reports are included in Appendix E. Table 1 summarizes the List of Target Analytes list for the Site. Figure 2 indicates the approximate locations of soil borings, test pits, hand auger borings, surface water staff gauges and groundwater monitoring wells at the Site.

4.1 Previously Existing Well Development and Groundwater Sampling

Proper well development is essential to promote the flow of representative groundwater into the well, remove sediment introduced into the borehole during the drilling process and improve the hydraulic connection between the monitoring well screen and the surrounding aquifer. Kimley-Horn reported total suspended solids (TSS) greater than 2,000 mg/L (as high as 4,800 mg/L) in groundwater samples collected from the three monitoring wells (MW-KH-1 through -3) installed during their assessment within the interior of the Site (within ash fill areas of the Site). Elevated TSS measurements suggest that the samples were turbid (may have contained sediment). As metals are naturally occurring in soil, groundwater samples that contain sediment or ash may produce metals results that are not representative of actual groundwater conditions.

During Phase I Site activities, MACTEC personnel gauged and re-developed the four previously installed monitoring wells at the site (the three installed by Kimley-Horn and one installed by URS). Development proceeded until development water from the wells appeared relatively clear (and turbidity readings using a water quality analyzer remained less than 250 nephelometric turbidity units [NTU]) or until 10 well volumes were removed. MACTEC personnel observed turbulence and apparent sediment entering the well screen at or near the surface of the water column in the Kimley-Horn wells during development. These observations suggest that the screen interval for these wells may be too close to the surface (within 2 feet) to have allowed for installation of both a proper sand pack above the top of the screen and a proper bentonite well seal above the sand pack (see Appendix D for a Typical Type II Well Construction Diagram).

Following well development performed in general accordance with the MACTEC SAPs, each well was allowed to recharge for 48 hours prior to sampling. After 48 hours, each of the 4 wells produced water samples with turbidity readings of less than 10 NTU (considered suitable for sampling in accordance with the SAP) and well purging was performed using a peristaltic pump and a flow-through cell. Water quality parameters (temperature, pH, turbidity, oxidation-reduction potential, conductivity and dissolved oxygen) in the flow-through cell were measured using a Horiba U22 water quality analyzer and recorded prior to sample collection. Groundwater purging and sampling records for each well are included in Appendix A. Stabilized water quality results for each well are presented on Table 2. Once water quality parameters stabilized, the flow-through cell was removed and a 0.45 micron filter was placed in-line for collection of a sample to be preserved and analyzed for dissolved metals. The in-line filter was then removed and groundwater samples were collected from the polyethylene tubing connected to the peristaltic pump for total metals and the remaining List of Target Analytes (see Table 1).

Groundwater sampling was performed in general accordance with the EPA Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures (Puls & Barcelona, 1996). Groundwater samples were containerized (with appropriate preservative, when applicable), placed on ice and shipped under Chain-of-Custody via Federal Express overnight delivery to TestAmerica for analysis. Laboratory analytical results for each of the existing wells installed by others are presented on Table 3.

4.2 Groundwater Monitoring Well Installation and Development

Sixteen (16) 2-inch inside-diameter (I.D.) Type II groundwater monitoring wells were installed around the perimeter of the Site in during Phase I Site activities and three (3) 2-inch I.D. Type II groundwater monitoring wells were installed within the southwest quadrant of the Site during Phase II Site activities. The borings were advanced using hollow-stem auger drilling techniques. Standard penetration tests and sampling was performed using the procedures described in ASTM D1586 continuously for the first 10 feet below grade and at 5-foot intervals thereafter. The field program was monitored by a Virginia Registered Professional Geologist. A MACTEC geologist provided oversight to log each boring and direct well installation. Borehole samples were classified according to their lithology and the depth of stratigraphic contacts was documented. Each soil sample was visually described and given an estimated classification in general accordance with the Unified Soils Classification System (USCS).

4.2.1 Monitoring Well Installation

During Phase I Site activities, eight 'shallow-depth' Type II wells were advanced to penetrate at least ten feet into the uppermost water-bearing zone (shallow well depths ranged from approximately 15 to 20 feet below grade). Eight 'intermediate-depth' Type II wells were advanced to the apparent base of the uppermost water-bearing zone (intermediate well depths ranged from approximately 35 to 44 feet below grade). Each well was constructed with pre-filter packed well screen, consisting of; a 10-foot section of 4-inch I.D. polyvinyl chloride (PVC) machine-slotted outer screen and a 10-foot section of 2-inch I.D. PVC machine-slotted inner screen with Morie #2 equivalent grade sand between the inner and outer screen sections. The remaining annular space around the well screen was filled with Morie #2 equivalent grade sand to stabilize the well, which was extended approximately two feet above the top of the slotted screen. A bentonite seal approximately two feet thick was placed above the sand pack and Portland cement/bentonite grout slurry was placed above the bentonite to seal the well at the ground surface and mitigate the potential for cross-contamination of the underlying aquifer.

The shallow- and intermediate-depth wells were installed in pairs at eight locations around the perimeter of the Site within an existing Dominion easement (see Figure 2). Three of the Type II well-pairs (MW-BGC-5, -6 and -7) were installed in areas inferred to be up-gradient of the ash fill and five Type II well-pairs (MW-BGC-8, -9, -10, -11 and -12) in areas inferred to be cross-gradient to down-gradient from the ash fill (wells were located outside of ash placement areas).

The Type II monitoring wells located along the south and east boundaries of the site (MW-BGC-8, -9, -10, -11 and -12) were completed with an approximate 3-foot standing riser cover with a hinged locking lid (due to the tall vegetation in this area) set into a 2-foot by 2-foot concrete pad. The Type II monitoring wells located along the north and west boundaries of the site (MW-BGC-5, -6 and -7) were completed with a locking well seal and an 8-inch diameter flush-mount manhole cover (due to the proximity of Centerville Turnpike and Whittamore Road and the landscaped nature of this area of the Site) set into a 2-foot by 2-foot concrete pad. Boring logs with well construction details are included in Appendix D, and Table 4 presents a summary of monitoring well construction data.

During Phase II Site activities, three additional 'shallow-depth' Type II wells were installed within the southwest quadrant of the Site (see Figure 2); two in the Dominion easement along the southern boundary of the Site (MW-BGC-13 and -14) and one within the golf course north of the tee box for hole #2 (MW-BGC-15). Each of the three additional new wells was installed consistent with the shallow-depth wells installed during Phase I, to depths ranging from 15 to 20 feet bgs, and completed with an approximate 3-foot standing riser cover with a hinged locking lid set into a 2-foot by 2-foot concrete pad. Boring logs with well construction details are included in Appendix D, and Table 4 presents a summary monitoring well construction data.

4.2.2 Well Development

MACTEC personnel gauged and developed each of the 19 new monitoring wells at the Site (MW-BGC-5A, -5B through -12A, -12B during Phase I and MW-BGC-13 through -15 during Phase II) in general accordance with the SAPs (see Appendix F). Well development was performed using a surge block and submersible pump to surge throughout the well screen and purge at least 10 well volumes from each well. Development was continued until ph and conductivity stabilized to within 10 percent and turbidity measurements were maintained below 50 NTUs (in general accordance with the U.S. EPA Standard Operating Procedure [SOP] for Monitor Well Installation, dated March, 18, 1996). No water from an outside source was introduced into the new wells during well development activities. Each properly developed well was then allowed to stabilize for a minimum of 48 hours prior to collection of a groundwater sample. Well development and purge water removed from the wells was placed into 55-gallon drums and labeled for temporary staging on the Site at a location designated by golf course personnel. See section 4.7 for waste characterization and disposal.

4.3 Staff-Gauge Installation, Survey, Surface Water Sampling, Slug Testing and Groundwater Sampling

Surface water staff gauges were installed, surveyed and monitored to evaluate surface water flow characteristics and to relate these to near-surface groundwater flow at the Site. Slug tests were performed on selected new monitoring wells at the site to evaluate groundwater flow characteristics. Groundwater samples were collected from each of the new monitoring wells to evaluate the concentration of total metals and selected ions.

4.3.1 Surface Water Staff-Gauge Installation

Nineteen surface water staff gauges (SG-1 through -19) were installed in ponds and drainage ditches at the Site (see Figure 3) during Phase I Site activities. Staff gauges were set approximately one to two feet below the water line at the time of installation (each gauge is approximately 3.34 feet in length and permanently marked at 0.01-foot intervals for visual observation of water levels relative to the bottom of the gauge). Ponds in this report will be referred to by their corresponding staff gauge identifier, where applicable (i.e. the pond with staff gauge SG-17 will be referred to as Pond 17).

4.3.2 Survey & Gauging

The location of the 19 new wells, 19 surface water staff gauges, 4 existing wells, 14 test borings and 3 test pits were surveyed by a Virginia licensed professional surveyor. The well locations were recorded using the Virginia State Plane coordinate system. The height of a reference survey datum, top of each staff gauge, a marked point on top of the inner well casing (TOC) and the ground-surface elevation of each well was established within ±0.01 foot in relation to mean sea level, which is established by reference to a National Geodetic Vertical Datum (see Table 4 for TOC and ground surface elevations at each well; see Table 5 for surface water staff gauge elevations). The static groundwater level in each of the wells installed during this investigation and the four existing wells installed by others was gauged and recorded on four separate occasions using an electronic water-level indicator (see Table 6). The water level at each staff gauge was also recorded during each well gauging event (see Table 5). Horizontal control for the hand auger borings was established using a portable hand-held Global Positioning System (GPS) unit.

4.3.3 Surface Water Sampling & Analysis

MACTEC collected surface-water samples from 12 selected staff gauge locations (SG-3, SG-4, SG-6 through -12, SG-16, SG-18, and SG-19) and 6 other selected surface-water locations (SW-20 through -25) throughout the site during Phase I Site activities (see Figure 3).

During Phase II Site activities, MACTEC collected surface-water samples from a total of six locations located within the southwest quadrant of the site, five previously sampled locations (SG-9 through -12 and SW-22) and one new location adjacent to well MW-BGC-8A (SG-13).

Surface-water sample locations are indicated on Figure 3 and are summarized as follows:

- SW-20 and SW-21 were collected from culvert drain pipes that enter the perimeter drainage ditch along the western Site boundary from the off-site commercial properties west of Centerville Turnpike

- SW-22, SW-23, SW-24 and SW-25 were collected from drainage ditches that enter the southern boundary ditch from the off-site residential properties south of the Site

- SG-4 was collected from the southern boundary ditch near the southeast corner of the Site where the ditch exits the Site

- SG-3, SG-6, SG-7, SG-8, SG-9, SG-10, SG-11, SG-12, SG-16, and SG-19 were collected from 10 of the 13 ponds on the Site (ponds with staff gauges SG-1, SG-2 and SG-17 were not sampled during this investigation)

- SG-18 was collected from the drainage ditch that exits the Site near the eastern Site boundary

- SG-13 was collected from the southern boundary drainage ditch adjacent to well MW-BGC-8A, within the southwest quadrant of the Site

Surface-water flow directions observed in the drainage ditches during sampling events and throughout this investigation are also indicated on Figure 3. See Table 1 for a List of Target Analytes and Table 7 for surface-water analytical results.

4.3.4 Slug Testing

During Phase I field activities, MACTEC performed an aquifer test (slug test) on monitoring well pairs MW-BGC-5, -6, -8, and -11 (four shallow and four intermediate-depth wells). During Phase II field activities, MACTEC performed slug testing on monitoring wells MW-BGC-13 through -15 and retesting of well MW-BGC-8A (four shallow depth wells). The retest of monitoring well MW-BGC-8A was performed due to insufficient data obtained during the initial test to evaluate aquifer characteristics from this well.

Following monitoring well installation and development, slug tests were performed in general accordance with ASTM Standard D 4044-91. Each slug test was performed by producing a near instantaneous change in head pressure in the monitoring well and measuring the subsequent water level response within the well. Head changes were induced by adding/removing a mechanical PVC "slug" from the water column inside the well. After the slug was added or removed from the well, the water level in the well was monitored using a pressure transducer with an internal datalogger, which recorded water level readings at regular, timed intervals. Water level readings were recorded beginning at least one to two minutes prior to introducing the PVC "slug" into the well to establish a baseline during the slug-in portion of the test. Readings continued as the water infiltrated into the aquifer until the water level had recovered to within 98% of the initial static groundwater level. A subsequent slug-out test was begun by quickly removing the PVC "slug" and monitoring recharge from the aquifer until the water level had recovered to within 98% of the initial static groundwater level. Data was evaluated using Aqtesolv for Windows, Version 3.50 Professional (HdyroSOLVE, 2003) and the Bouwer and Rice Method (Bouwer and Rice, 1976) to produce hydraulic conductivity estimates for each well (see Table 8 for a summary of slug test results). Due to rapid recharge from the generally sandy soils within the screened interval of the wells, slug tests produced a limited amount of quality data for analysis (see Appendix B). In addition to slug tests performed during this investigation, literature references to typical ranges of hydraulic conductivity for the soil types encountered within the screened interval of wells installed at the Site were also considered in the hydrogeologic evaluation.

4.3.5 Groundwater Sampling & Analysis (New Wells)

MACTEC personnel completed two groundwater sampling events (December 2008 and June 2009) from wells installed during this investigation. During Phase I Site activities groundwater samples were collected from the 16 new monitoring wells (MW-BGC-5A, -5B through -12A, -12B) and the four existing wells. During Phase II Site activities, groundwater samples were collected from the same 16 monitoring wells (MW-BGC-5A, -5B through -12A, -12B) and the 3 additional shallow wells (MW-BGC-13 through -15). Groundwater samples from the wells were collected no sooner than 48 hours after final development. After 48 hours, each of the wells produced water samples with turbidity readings of less than 10 NTU (considered suitable for sampling in accordance with the SAP) and well purging was performed using a peristaltic pump and a flow-through cell. Water quality parameters (temperature, pH, turbidity, oxidation-reduction potential, conductivity and dissolved oxygen) in the flow-through cell were measured using a Horiba U22 water quality analyzer and recorded prior to sample collection. Groundwater purging and sampling records for each well are included in Appendix A. Stabilized water quality results for each well are presented on Table 2. Once water quality parameters stabilized, the flow-through cell was removed and groundwater samples were collected from the polyethylene tubing connected to the peristaltic pump. Groundwater sampling was performed in general accordance with the EPA Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures (Puls & Barcelona, 1996). Groundwater samples were appropriately containerized (with appropriate preservative, when applicable), placed on ice and shipped under Chain-of-Custody via Federal Express overnight delivery to TestAmerica in Nashville, TN for analysis. Table 1 presents the List of Target Analytes for each groundwater sample collected at the Site during this investigation. Laboratory analytical results for the shallow and intermediate-depth wells installed during this investigation are presented on Tables 9 and 10, respectively.

4.4 Soil Cover and Ash Fill Assessment

Test borings, hand auger borings and test pits were advanced to evaluate the soil cover and ash fill. A MACTEC engineer and geologist were on-site to direct the field exploration program and prepare field logs of borings and test pits.

4.4.1 Ash Fill Test Borings

During Phase I Site activities, ash fill and subsurface conditions were explored with three widely spaced soil test borings. Actual soil test borings were located by MACTEC personnel at locations of anticipated maximum fill depth, primarily on the top of highest topographic mounds, located in separate areas of the golf course. The boring locations (SB-1, SB-2 and SB-3) are shown on Figure 2.

Test borings SB-1, SB-2 and SB-3 encountered top cover soils, ash fill, and residuals soil. Subsurface conditions encountered at the boring locations are shown on the Test Boring Records in Appendix D. These Test Boring Records represent our interpretation of the subsurface conditions based on the field logs and visual examination of the field samples by MACTEC personnel. The lines designating the interfaces between various strata on the Test Boring Records represent the approximate interface locations.

The Phase I test borings were advanced using mud-rotary drilling techniques through the ash fill to the residual soils below, each to an approximate depth of 22 feet below existing grade. Standard penetration tests and sampling was conducted using the procedures described in ASTM D1586 at 2-foot intervals on a continuous basis. Undisturbed tube samples of the ash fill were collected in general accordance with the procedures described in ASTM D1587. Each undisturbed tube sample was submitted for vertical permeability (falling head) analysis (see Appendix C for physical testing results). Upon termination of each boring, bentonite grout was placed using standard tremi-pipe techniques.

During Phase II Site activities, ash fill and subsurface conditions within the southwest quadrant of the Site were explored further with 11 additional test borings (SB-4 through SB-14). The primary objective for these borings was to confirm the limits of ash fill in the southwest quadrant of the Site (northeast of monitoring well MW-BGC-8A). These borings (SB-4 through SB-14) were completed to a maximum depth of 8 feet bgs using a Geoprobe® rig. MACTEC Test Boring Records are included in Appendix D.

4.4.2 Test Pits

During Phase I Site activities, soil cover and ash fill was evaluated by advancing three widely spaced test pits (TP-1, TP-2 and TP-3). Actual test pits were located by MACTEC personnel near the toe of the slope of each of the three highest topographic mounds, located in separate areas of the golf course. The three test pits were excavated into the ash fill at each location using a rubber-tire backhoe to depths ranging from 2.8 to 3.8 feet below existing grade. As the test pits were excavated, in-place density tests were performed. Bulk samples were obtained for physical testing in the laboratory. The test pit locations (TP-1, TP-2 and TP-3) are shown on Figure 2.

Nuclear gauge density tests were performed in accordance with ASTM D2922 on the materials encountered in the test pit excavations at various depths within the ash fill. Bulk ash fill samples were collected from each test pit and submitted to MACTEC's geotechnical laboratory in Abingdon, Virginia for standard Proctor compaction tests and moisture content tests. Results of the nuclear gauge density tests and standard Proctor compaction test were compared for relative in-place compaction. The results are contained as Compaction Test Results in Appendix C and discussed in Section 5.5.2.

One ash fill sample from each test pit, near the base of the ash fill (for a total of three ash samples) was submitted to TestAmerica for pH and Toxicity Characteristic Leaching Procedure (TCLP) metals analyses (see Table 11). In addition, the following analytical instruments were utilized to evaluate the contents of three ash fill samples (one from each test pit), an ash sample provided by Dominion from Chesapeake Energy Center (utilized as an un-amended fly ash reference sample) and a kiln dust sample from Chemstone Corporation (utilized as amending agent reference sample):

- Stereomicroscopy
- Polarized Light Microscopy (PLM)
- Scanning Electron Microscopy (SEM)
- Energy Dispersive X-Ray (EDX)
- X-Ray Diffraction (XRD)
- X-Ray Fluorescence (XRF)

See Table 12 for a summary of results from the ash content analyses. Following completion of the test pits, material excavated from the test pits was used as backfill and compacted using a hand-operated gasoline vibratory compactor and jute matting was placed over the disturbed area to mitigate erosion.

4.4.3 Soil Cover Assessment

During Phase I Site activities, 33 hand-auger borings were advanced at the Site in areas of ash fill to evaluate the thickness and physical properties of the soil cover above the ash fill. Hand auger locations were generally spaced in an approximately 300-feet by 300-feet grid layout, except where a grid was comprised of ponds, golf fairways or greens (see Figure 6 for hand auger boring locations and observed cover thicknesses). The hand auger borings, test borings and test pits were located in the field by MACTEC personnel by referencing site features shown on plans and aerial photographs and utilizing a conventional GPS instrument. Each hand auger boring was advanced until apparent ash fill was encountered (depths ranging from 4 to 66 inches below grade). See Table 13 for a summary of soil cover physical properties and thicknesses.

Three representative locations were selected for collection of undisturbed tube samples of the soil cover using the procedures described in ASTM D1587. Each undisturbed tube sample was submitted for vertical permeability (falling head) analysis (see Appendix C for physical testing results). Upon completion of sampling, the borings were backfilled with the hand auger cuttings.

4.5 Pond Depth Gauging and Sediment Sampling

During Phase II Site activities, 4 surface water ponds in the southwest quadrant of the Site (Ponds SG-9 through SG-12) were gauged at approximately 10-foot intervals along the approximate center length of each pond to measure the depth to the bottom below the water surface (see Figure 2). In addition, a total of eight sediment samples were collected from the ponds (two per pond) utilizing a stainless steel soil trap and submitted for laboratory analysis to evaluate the pond sediment for potential constituents of ash.

4.6 Soil, Road Bed, and Stockpile Sampling

During Phase II Site activities, MACTEC utilized a hand auger to collect six soil samples from the stream/pond banks in the vicinity of staff gauges SG-9, SG-10, SG-11, SG-12, SW-13, and SW-22 to evaluate potential acid sulfate soils in the southwest quadrant of the Site. The stream/pond-bank samples, collected approximately 6 to 24 inches bgs proximal to surface water at each location, were submitted for laboratory analysis.

MACTEC utilized a hand auger to collect four shallow road-bed samples (RB-1 through -4) from the access road located along the southwest perimeter of the Site. Shallow road-bed samples were collected from grade to approximately six inches bgs. MACTEC also utilized a hand auger to collect four composite soil samples from soil stockpiles located near the southern boundary of the Site, between monitoring wells MW-BGC-8A and MW-BGC-13. The four shallow road-bed samples and the four composite stockpile samples were submitted for laboratory analysis to evaluate the samples for potential constituents of ash.

4.7 Construction Documents Review

MACTEC reviewed available construction documents for the Battlefield Golf Club, formally Etheridge Greens Golf Course, located in Chesapeake, Virginia. The following documents related to ash amendment and construction were provided by Dominion or downloaded from;

http://www.cityofchesapeake.net/services/citizen_info/battlefieldgolfclub/:

- Construction Quality Assurance Plan dated March 7, 2002, by Combustion Products Management, Inc. of Chesapeake, Virginia.
- Submission Information Regulations Governing Management of Coal Combustion By-Products 9 VAC 20-85 for Etheridge Greens Golf Course, Chesapeake, Virginia, dated March 7, 2002, by Combustion Products Management, Inc of Chesapeake, Virginia.
- Density Reports dated from May 17, 2002 to February 5, 2007 completed by McCallum Testing Laboratories, Inc. of 1808 Hayward Avenue, Chesapeake, Virginia.
- Amended Ash Quality Control Program for Etheridge Greens Gold Course, Chesapeake, Virginia, dated February 2002, by VFL Technology, Inc., West Chester, Pennsylvania.
- MJM_Golf_Documents.pdf, http://www.cityofchesapeake.net/services/citizen_info/battlefieldgolfclub/index.shtml#SiteTestReports
- Tidewater_DEQ.pdf, http://www.cityofchesapeake.net/services/citizen_info/battlefieldgolfclub/index.shtml#SiteTestReports

MACTEC reviewed the quality assurance requirements that were listed in the document titled "Construction Quality Assurance Plan" dated March 7, 2002. MACTEC also reviewed the available test reports from McCallum Testing Laboratories.

4.8 Equipment Cleaning

Equipment cleaning procedures outlined in the SAPs were followed during sampling to prevent false detections that can occur when outside contaminants are introduced to the media being sampled. Wherever possible, sufficient clean equipment (i.e. sample tubing) was transported from the office to the Site to minimize equipment re-use and cleaning. Equipment rinse blanks were collected to assess the equipment being used and to confirm the effectiveness of the cleaning procedures.

4.9 Waste Characterization and Disposal

As a result of field activities conducted during the investigation, non-hazardous waste materials were generated. These wastes included drill cuttings from soil borings, personal protective equipment, and water generated during the development, purging, and sampling of monitoring wells and rinse water generated during cleaning events. Waste material was placed into 55-gallon drums and labeled for temporary staging on the Site at a location designated by golf course personnel. Waste material was transported for off-site disposal by Clean Harbors Environmental Services, Inc. (Clean Harbors) and disposal manifests are included in Appendix G.

4.10 Quality Assurance

During Phase I Site activities, three quality assurance (QA) duplicate samples (MW-DUP-1, MW-DUP-2 and MW-Dup-3) were collected with the groundwater samples and two (SW-DUP-1 and SW-DUP-2) were collected with the surface water samples for the same analyses as the primary samples. Sample results from the duplicate samples were compared to the primary sample results to evaluate repeatability of the data. Two rinse blank samples were collected for the same analyses to evaluate the quality of cleaning procedures; one (identified as SW-BGC-Rinse1) utilizing the surface water sampling apparatus after cleaning and a second (identified as RINSE BLANK) utilizing the groundwater sampling apparatus after cleaning. One field blank sample was also submitted to the laboratory for analysis as QA of the laboratory supplied de-ionized water and analytical procedures.

During Phase II Site activities, two QA duplicate samples (MW-BGC-DUP03 and MW-BGC-DUP04) were collected with the groundwater samples and one (SW-BGC-DUP052709) was collected with the surface water samples for the same analyses as the primary samples. These sample results were utilized to evaluate repeatability of the data. Three rinse blank samples were collected for the same analyses to evaluate the quality of cleaning procedures; two (MW-BGC-RB03 and MW-BGC-RB04) utilizing the groundwater sampling apparatus after cleaning and one (SW-RinseBlank 052709) utilizing the surface water sampling apparatus after cleaning was also submitted to the laboratory for analysis as QA of the laboratory supplied de-ionized water and analytical procedures.

During Phase II Site activities, six QA duplicate samples were also collected with the following media for the same analyses as the primary samples:

- pond sediment: PS-BGC-Dup-01
- Geoprobe ash: SB-BGC-DUP 01
- stream-bank soil: HA-BGC-DUP01
- road-bed soil: HA-BGC-RB-DUP
- stockpile soil: SP-BGC-DUP01
- monitoring well soil: MW-BGC-DUP01

These duplicate sample results were compared to the primary sample results to evaluate repeatability of the data.

MACTEC reviewed the laboratory data reports provided by TestAmerica for samples collected during both phases of this investigation. Based on the data quality review, the data appears acceptable with respect to accuracy, precision, representativeness, completeness and, therefore, has been determined to be appropriate for its intended use. Quality control samples including equipment rinse blanks, field duplicate samples and the field blank sample further indicated that the analysis of these samples were within the appropriate quality control criteria. Sampling and analysis work was performed in general accordance with the SAPs.

5.0 INVESTIGATION FINDINGS

The following sections detail the results and findings of MACTEC's two phases of field investigations.

5.1 Geologic Findings

Two basic natural stratigraphic units were encountered at the site beneath and outside of the ash fill areas. Our observations regarding these natural stratigraphic units were generally consistent with the geologic findings reported by URS for the Site. A description of the ash fill and soil cover (where applicable) and the two basic natural strata are briefly described in the following paragraphs. Cross sections for the Site are included as Figures 4 and 5, which conceptually illustrate the raised topography of the golf course where ash fill has been placed, surface water features and subsurface stratigraphy interpreted from the boring logs. A topographic survey was not performed for this investigation and the cross sections were prepared based upon visual observations and surveyed data for test borings, test pits, hand auger borings and monitoring wells installed by MACTEC during this investigation. The boring logs and cross sections represent the interpretation of the subsurface conditions based on visual examination of field samples. The lines designating the interfaces between various strata on the boring records and cross sections represent the approximate interface; however, the actual transitions between strata may be gradual.

Soil Cover (earthen fill material): In interior areas of the Site where ash fill was encountered, ranging in thickness from 4 to 66 inches, soil cover was generally described as fine-grained material, composed of clayey silt, silty fine-grained sand with varying clay content and silty clay. See Figure 6 for a map of soil cover thicknesses above the ash fill. See Table 13 for a summary of soil cover material encountered in each hand auger boring. Based on the results of vertical permeability (falling head) analyses performed on three soil cover tube samples, coefficients of permeability for soil cover ranged from 4.2×10^{-07} to 8.4×10^{-06} centimeters per second (cm/sec), see Appendix C. These results indicate that the soil cover has a relatively low permeability.

Ash Fill: Encountered beneath the Soil Cover in each of the following Phase I samples locations: 33 hand auger borings, 3 interior test borings and 3 test pits. The ash fill was not fully penetrated in the hand auger borings or test pits, but ranged in thickness from approximately 15.5 to 17 feet (to depths of up to approximately 19 feet bgs) in the 3 interior test borings advanced in the highest topographic points at the Site. Ash fill was described as dark gray to black, silty, very fine-grained sand or very fine-grained sandy silt. The consistency of ash fill encountered in the hand augers was described as firm to semi-consolidated. Based on the results of vertical permeability (falling head) analyses performed on three ash fill tube samples, coefficients of permeability for ash fill ranged from 6.9×10^{-07} to 9.5×10^{-06} cm/sec, see Appendix C. These results indicate that the ash fill has a relatively low permeability.

STRATUM A (interpreted as Columbia Group): Dark brown to gray or black, organic clayey silt and clay with sand was encountered directly beneath the ash fill (in each of the 3 test borings) to depths of up to approximately 21 feet bgs and in areas outside the ash fill (in each of the 19 monitoring wells) from the ground surface to depths of approximately 7.5 feet bgs. Beneath this dark, generally organic fined-grained sediment in the upper portion of Stratum A, a gray or light gray, clayey fine-grained sand was encountered in each of the monitoring wells, grading to become more coarse-grained with depth with some interlayered clay and trace shell fragments.

STRATUM B (interpreted as upper Yorktown Formation): Encountered in each of the 8 intermediate depth monitoring wells at depths ranging from 33 to 42.5 feet below grade. Consists of light to dark greenish-gray medium-grained sand and sandy clay. Stratum B was only partially penetrated (less than 5 feet of the upper portion) during this investigation.

5.2 Hydrogeologic Findings

Groundwater was encountered at depths ranging from approximately 2.3 to 10.0 feet below ground surface at the Site on July 15, 2009 (see Table 4). Groundwater elevation data for the Site is presented in Table 6. The water levels and monitoring well elevations were used to develop groundwater contour maps for the December 10, 2008 and June 16, 2009 gauging events (Figures 7 through 10). Figures 7 and 8 were developed utilizing water level data from the shallow monitoring wells and surface-water staff gauges. Figures 9 and 10 were developed utilizing water level data from the intermediate-depth wells only. Based on water level data from the shallow monitoring wells and surface water staff gauges, groundwater flow is interpreted to be in a generally southeast direction, toward or in the direction of the nearest surface water drainage features. A more southerly flow direction is apparent in the uppermost shallow water table along the southwest and southern border of the site, where the drainage ditch appears gaining with groundwater flow toward the ditch (see Figures 7 and 8). This localized southerly flow direction is muted or not apparent in the lower portions of the water table aquifer based on water level data from the intermediate depth wells (see Figures 9 and 10).

A comparison of groundwater elevations between the shallow and intermediate-depth wells at most paired well locations at the Site indicates a slight upward vertical gradient during the June 16, 2009 gauging event (an average pressure head difference of approximately 0.08 foot) and a slight downward vertical gradient during the July 15, 2009 gauging event (an average pressure head difference of approximately -0.10 foot). Based on the groundwater contour maps from the two gauging events performed, horizontal gradients across the Site during this investigation generally ranged from approximately 0.002 (northern portion of the site) to 0.008 (southwestern portion of the Site, near the drainage ditches). Slug test data performed on the wells during this investigation (MW-8A, MW-13 and MW-15) indicated hydraulic conductivities ranging from approximately 4.6 to 9.5 ft/day (1.6×10^{-3} to 3.3×10^{-3} cm/sec) for a site average of approximately 3.6 ft/day (1.3×10^{-3} cm/sec). Based on the percentage (2.9 to 19.7 percent) of fines (passing a #200 sieve) encountered in the soil samples collected from the screened interval of wells installed at the Site (see Table 8), the effective porosity is anticipated to range from approximately 20 to 45 percent (Johnson, 1967). Published literature values of hydraulic conductivity for the soil types encountered at the Site range from 0.1 ft/day (4×10^{-5} cm/sec) for clayey fine-grained sand to 10 ft/day (4×10^{-3} cm/sec) for clean fine-grained sand (USBR, 1977), for a Site average of approximately 3 ft/day (1.1×10^{-3} cm/sec). Based on this range of hydrologic properties for the Site, groundwater flow velocities are anticipated to range from approximately 16 to 23 feet per year (see Table 8). Seasonal water table fluctuations, possible tidal fluctuations and variations in daily demand on local groundwater withdrawal were not evaluated during this investigation and may influence the actual groundwater gradient, flow direction and groundwater velocity at the Site.

5.3 Environmental Laboratory Results

Analytical results for groundwater samples collected at the Site during this investigation are presented on Table 3 (existing well results), Table 9 (shallow well results) and Table 10 (intermediate-depth well results). Analytical results for surface-water samples collected at the Site during this investigation are presented on Table 7. Analytical results for ash fill samples submitted for metals analysis by the Toxicity Characteristic Leaching Procedure (TCLP) are presented on Table 11. TCLP metals results for ash fill samples are discussed in Section 5.3.1 below. A comparison of the detected analytes in surface water and groundwater to risk screening criteria is discussed in Sections 5.3.2 and 5.3.3 below. Analytical results for the pond sediment and soil stockpile and red bed samples are presented on Appendix E Tables 2 and 3 and are discussed in Sections 5.3.5 and 5.3.6 below.

5.3.1 Potential Constituents of Concern (COCs) in Groundwater

U.S. EPA Region III has established maximum contaminant levels (MCLs) for drinking water for a variety of analytes. Detected analytes in groundwater samples collected during this investigation were compared to the MCLs and Virginia Water Quality Standards (see Tables 9 and 10). A summary of analyte concentrations detected, compared to applicable standards and previous samples collected at the Site prior to construction is presented below.

<u>pH</u>

The Virginia Groundwater Standards indicates a pH range for groundwater in the Coastal Plain Physiographic Province of 6.5 to 9. Comparatively low pH (<6.5) was measured in groundwater samples collected from 19 of 23 monitoring wells at the Site, including groundwater samples collected from 2 of 3 wells sampled by URS during their pre-construction assessment. The most notable low pH (<4) measurements were identified in shallow groundwater samples collected from monitoring well MW-

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BGC-8A. A thorough assessment of the geochemistry of soil and its interaction with groundwater at the Site is beyond the scope of this investigation, however, low pH groundwater conditions generally increase metals concentrations in groundwater as naturally occurring metals are more readily leached from the soil where low pH conditions occur. The relatively low pH conditions identified in groundwater at the site may be attributed to naturally occurring sulfate-bearing soils (potential peroxide acidity [PPA] testing of soil was performed to confirm the presence of potential acid producing soils at the Site).

Antimony

During the Phase I sampling event in November/December 2008, antimony concentrations were less than the MCL of 0.006 mg/L in groundwater samples collected from all but 4 of the 20 monitoring wells (MW-BGC-7A, -7B, -8A, and -11A). However, antimony was also detected in the laboratory method blank for the analytical run that produced results exceeding the MCL and the results are reported as biased high (may not be representative of actual antimony concentrations in groundwater). During the subsequent Phase II sampling event in May/June 2009, antimony results were less than the laboratory reporting limit of 0.01 mg/L.

Arsenic

During the Phase I sampling event in November/December 2008, arsenic concentrations were less than the MCL of 0.01 mg/L in groundwater samples collected from all but 1 of the 20 monitoring wells (MW-BGC-12A and the corresponding duplicate MW-Dup-3 at concentrations of 0.0205 and 0.0195 mg/L, respectively). However, the arsenic result for the groundwater sampled collected from this well during the Phase II sampling event in June 2009 was less than the laboratory reporting limit of 0.01 mg/L. During the Phase II sampling event in June 2009, arsenic concentrations in groundwater samples were less than the MCL of 0.01 mg/L in groundwater samples collected from all but 1 of the 19 monitoring wells (MW-BGC-15 and the corresponding duplicate MW-BGC-DUP04 at concentrations of 0.0336 and 0.0332 mg/L, respectively). Arsenic and other heavy metals are common agricultural contaminants in soil and may be present in groundwater as possible pesticide by-products. The Site was formerly cultivated for agricultural use and surrounding properties north of the Site remain active agricultural fields. Arsenic was not detected in the one remaining URS well (MW-URS-2) sampled during this investigation or during the pre-construction sampling event performed at the Site by URS.

Beryllium

During the Phase I sampling event in November/December 2008, beryllium concentrations were less than the MCL of 0.004 mg/L in groundwater samples collected from all but 1 of the 20 monitoring wells (MW-BGC-8A at a concentration of 0.0149 mg/L. During the subsequent Phase II sampling event in May/June 2009, beryllium concentrations were less than the MCL in groundwater samples collected from all but 2 of the 19 monitoring wells (MW-BGC-8A, the corresponding duplicate from this well and MW-BGC-13 at concentrations of 0.0078 mg/L and 0.0145 mg/L, respectively). Monitoring wells MW-BGC-8A and -13 produced groundwater samples with relatively low pH measurements (3.98 and 5.20, respectively). Beryllium is a naturally occurring element and is readily leached from soil under low pH conditions.

Zinc

The EPA has not established an MCL for zinc, however, the Virginia Groundwater Standard (VGS) for zinc is 0.05 mg/L. Zinc concentrations were less than the MCL in groundwater samples collected during both phases of the investigation from all but nine monitoring wells (MW-KH-1, KH-2, KH-3, BGC-5A, -8A, -10A, -12B, -13 and -15). Zinc concentrations detected in groundwater samples ranged from 0.0523 mg/L (KH-3) to 1.29 mg/L (KH-2). Monitoring wells that produced samples exceeding the VGS also produced samples with relatively low pH (<6.5) measurements. Zinc is a naturally occurring element and is readily leached from soil under low pH conditions.

5.3.2 Potential Constituents of Concern (COCs) in Surface Water

Surface-water analytical results were compared to corresponding Virginia In-Stream Standards for both public water supplies and for other surface water bodies not utilized as a public supply (see Table 7). The following analytes were detected at concentrations exceeding the corresponding standards.

pH

Relatively low (<4) pH results were measured in surface water samples collected from a pond near the southwest corner of the Site (staff-gauge location SW-BGC-SG12) and in a tributary drainage ditch (SW-22) that flows north from the residential community south of the Site into the drainage ditch along the southern boundary of the Site (see Figure 3 for surface water sample locations).

Mercury

Mercury was not detected in on-Site ponds or drainage ditches leaving the Site. However, mercury was detected in two surface water samples (SW-21 and SW-23) collected from tributary ditches that flow north from the residential development south of the Site into the drainage ditch along the southern boundary of the Site (see Figure 3 for surface water sample locations). Mercury concentrations detected in samples from SW-21 and SW-23 (0.000197 and 0.000188 mg/L, respectively) exceeded the corresponding Virginia Surface Water Standard for surface water bodies not utilized as a public water supply (0.000051 mg/L). However, both mercury results were indicated by the laboratory as estimated values due to detection above the method detection (0.00015 mg/L), but less than the laboratory detection limit.

5.3.3 TCLP Metals Results for Ash Fill

Toxicity Characteristic Leaching Procedure (TCLP) a laboratory method that simulates the leaching potential of constituents from a sample media. Three ash fill grab samples were analyzed for TCLP metals, see Table 11 Arsenic, silver and mercury TCLP results were less than the laboratory reporting limit for each of the ash fill samples collected, which were less than the regulatory limits for hazard classification as a characteristic hazardous waste for each of the ash fill samples. Table 15 summarizes other results of the ash fill samples.

5.3.4 Potential Peroxide Acidity (PPA) Results in Soil

PPA is a laboratory method that rapidly oxidizes a sample with hydrogen peroxide and then quantifies the amount of acidity produced. PPA results are expressed in tons of calcium carbonate ($CaCO_3$) required to neutralize 1,000 tons of material, which is an important measurement for agricultural purposes. PPA results for 12 of 16 soil samples collected from various depth intervals at the Site indicate that acid sulfate soils (defined as, requiring >5 tons of $CaCO_3$ per 1,000 tons of soil to neutralize) are present that have the potential to produce acid runoff when exposed to weathering (a naturally occurring condition documented for this region of Virginia). PPA results for soil samples collected from the Site ranged from neutral pH to approximately 22.6 tons of $CaCO_3$ per 1,000 tons of soil (see Table 16). As potential acid-producing soils have been identified at the site, relatively low pH measurements identified in groundwater and surface-water samples collected prior to construction and during this investigation appear to be naturally occurring.

5.3.5 Road Bed and Soil Stockpile Results

In general, metal concentrations in road bed and soil stockpile samples were less than (up to one order of magnitude) the average corresponding metal concentrations in ash fill samples (see Table 17). These results indicate that road bed and soil stockpile samples do not consist of ash.

5.3.6 Pond Sediment Sample Results

In general, metal concentrations in pond sediment samples were less than (up to one order of magnitude) the average corresponding metal concentrations in ash fill samples (see Table 18). These results indicate that pond sediment samples do not consist of ash.

5.4 Construction Documents Review Findings

A review of construction documents provided or available to us at the time of this report are listed below in Section 7.0. Our review of these documents generally leads us to conclude that efforts were made to place fill materials within parameters set forth in construction documents. The construction documents outlined testing procedures and documentation procedures that verify the integrity of the materials placed. Within the documents reviewed there is evidence that effort was set forth by the contractor to place the fill within the specified parameters. A total of 412 nuclear gauge density tests were documented and provided to us for review. Relative compaction ranged from 90.8 percent to 143.3 percent with an average of 102.4 percent. Relative compaction results that are above 100 percent generally indicate that there was a change of material as related to the standard Proctor test. Although some of the density tests recorded were less than the specified 95 percent compaction, it is possible that retests were taken to correct these areas.

Documents were provided from Chesapeake Energy Center - Dominion Generation, project number C-1653, for percent cement, used for amending agent in ash fill. Continuous monthly documentation was provided from April 2002 to March 2007.

5.5 Geotechnical Assessment Findings

5.5.1 Soil Cover

The top cover material encountered above the ash fill consisted of brown to dark brown and gray, stiff to firm, clay and silt soils. Organic material encountered was typically rooting mass from grass at the ground surface. Cover thickness and physical descriptions are indicated on Table 13 and are presented on Figures 4, 5, and 6. Soil cover was observed overlying the ash fill at an average thickness of 22-inches where ash fill was encountered in the hand auger borings. Soil cover was observed in the test borings and test pits at thicknesses ranging from 19.2 to 30.0 inches. Soil cover thickness exceeded 18 inches above the ash in 24 of the 33 hand-auger borings. Nine hand auger borings (C5, C7, D3, E4, F2, G6, G7, H7, and H13) encountered soil cover at thicknesses less than 18 inches, ranging from 4 to 17 inches (see Figure 6 for the estimated areas with cover less than 18 inches).

5.5.2 Ash Fill

Ash fill encountered in the test pits was described as gray to black, very loose to dense silt and very-fine grained sand. Results from the particle identification evaluation were generally inconclusive in determining the percentage content of kiln dust as an amending agent in the ash fill encountered at the Site (see Table 12). According to documents provided by Dominion the amending agent was added based upon a 2% target with a 1.5% minimum. Trace minerals present in the ash fill could not be conclusively identified to confirm the kiln dust content (the limit of detection [LOD] by the various methods utilized was reportedly about 1%). The exposure of ash fill to weathering since placement of the ash in 2001 to 2004 may have reduced the presence of lime and other calcium minerals. The laboratory reported that calcium was determined to be a substantial component of both the ash standard (approximately 2.37% as calcium oxide [CaO] by weight, primarily in the form of calcite) and the kiln dust standard (approximately 90.1% as CaO by weight, primarily as lime and other calcium minerals). Based on the XRF results, CaO concentrations by weight for the ash fill samples ranged from 3.45 to 5.75% (or at percentages of approximately 1.1 to 3.4 higher than in the ash standard). Ignoring morphologic differences between the samples, the higher CaO concentrations in the ash fill samples than in the ash standard suggest the presence of a calcium amendment, although the percentage of kiln dust was not confirmed.

Based on the tests MACTEC performed on the ash fill and our review of the construction documents, it can generally be confirmed that compactive energy was applied to the ash fill when placed. Relative compaction values of approximately 84, 87 and 92 percent as compared to standard Proctor for the in-place ash fill were estimated for the three test pit locations (see Appendix C). The moisture content of ash fill tested when compared to standard Proctor optimum moisture content were approximately 120 percent, 126 percent, and 130 percent. The ash fill that was tested for in-place density and moisture content was wet of the optimum moisture content as compared to the standard Proctor, but the in-place density of soils can vary based on the moisture content and it is likely that the affects of water infiltration has changed the moisture content of the ash fill from its original moisture content when placed. The specific degree of compaction at placement was not quantified from the results of this assessment due to potential post-placement expansion and changes in moisture content.

The ash fill thickness was observed being 15.2-feet 15.5-feet, and 17.2-feet in the 3 test borings. The Standard Penetration Test N-values obtained in the ash fill material ranged from weight of hammer (WOH) to 38 blows per foot. Lower consistency material was typically encountered near the interface with residual soils at the base of the ash fill. Samples subjected to laboratory moisture testing indicated that moisture generally increased with depth of ash fill.

A layer of apparent clayey fill material (tan to gray, very soft to firm clay with lenses of ash and fine to medium sand) was encountered beneath the ash fill at depths of 19-feet, 18-feet, and 17.3-feet below ground surface and typically ranged from 6 to 34 inches in thickness. Residual soils encountered beneath the clayey fill consisted of gray to brown, very soft, very loose to firm, sandy soils. Sandy soils encountered were typically fine to coarse, poorly graded to well-graded, and wet. These soils were encountered at 19.5-feet, 18.6-feet, and 21.0-feet bgs.

6.0 SUMMARY AND CONCLUSIONS

- Proper development of monitoring wells installed by Kimley-Horn (MW-KH-1, -2 and -3), followed by low-flow sampling to produce non-turbid samples resulted in substantially reduced metals concentrations for the wells compared to previous sampling performed by Kimley-Horne. Observations made by MACTEC personnel during sampling indicate that the screen interval for these wells may be too close to the surface (within 2 feet or less) to have allowed for installation of a proper sand pack above the top of the screen and installation of a proper bentonite well seal above the sand pack. Due to the location of these wells within the ash fill area of the Site, improper well construction may allow for ash to enter the well. MACTEC recommends that these wells be properly abandoned. If wells are considered necessary within this area of the Site, then replacement with properly constructed wells is recommended to prevent possible cross-contamination from ash intrusion.

- The Virginia Groundwater Standards indicates a pH range for groundwater in the Coastal Plain Physiographic Province of 6.5 to 9. Comparatively low pH (<6.5) was measured in groundwater samples collected from 19 of 23 monitoring wells at the Site, including groundwater samples collected from 2 of 3 wells sampled by URS during their pre-construction assessment. PPA results for soil samples collected from various depth intervals at the Site indicate that acid sulfate soils are present that have the potential to produce acid runoff when exposed to weathering (a naturally occurring condition documented for this region of Virginia). As potential acid-producing soils have been identified at the site, low pH measurements identified in groundwater samples collected prior to construction and during this investigation appear to be naturally occurring. The most notable low pH (<4) measurements were identified in shallow groundwater samples collected from monitoring well MW-BGC-8A (screened from 10 to 20 feet below grade) and in proximal surface water (Pond SG12 near the southwest quadrant of the Site and a stream that flows north into the southern boundary drainage ditch from the off-site residential development). A relatively low pH of 5.2 was measured in a groundwater sample collected from monitoring well MW-BGC-13, which is also in the southwest quadrant of the Site.

- Beryllium was detected in groundwater samples collected from two monitoring wells (MW-BGC-8A and MW-BGC-13) at concentrations exceeding the MCL. Arsenic was detected at concentrations exceeding the MCL in groundwater samples collected from monitoring well MW-BGC-12A during the Phase I sampling event in December 2008, but was less than the laboratory reporting limit during the Phase II sampling event in June 2009. Arsenic was detected at concentrations exceeding the MCL in the groundwater samples collected from monitoring well MW-BGC-15 during the Phase II sampling event in June 2009. Although fly ash is known to be a potential source for heavy metals such as arsenic and beryllium, elevated concentrations of these and other heavy metals were generally absent from groundwater samples collected from monitoring wells throughout the Site.

- The elevated arsenic and beryllium concentrations detected in groundwater samples collected from monitoring wells MW-BGC-8A and MW-BGC-13 are not suspected to indicate impact from ash fill at the Site, but may be related to acid producing soils and relatively low pH groundwater conditions in the southwest quadrant of the Site. However, further groundwater sampling would be necessary to confirm the results for wells installed during Phase II and evaluate potential trends in groundwater conditions throughout the Site.

- Groundwater flow beneath the Site is generally to the east-southeast, toward or in the direction of the nearest drainage ditch. Based on slug test data, groundwater level data obtained during this investigation and soil types encountered within the water table aquifer, the groundwater velocity across the Site is estimated to range from approximately 16 to 23 feet per year (although fluctuations in the groundwater gradient due to natural and man-made influences may occur to alter these velocity estimates). Transport velocities of potential contaminants would be substantially slower than groundwater velocity due to the effects of dilution and retardation (sorption, dissolution, and precipitation). Supplementary water-level gauging would be necessary to further evaluate seasonal variations in the groundwater gradient and flow direction at the Site.

- In general, metal concentrations in road bed, soil stockpile and pond sediment samples were less than (up to one order of magnitude) the average corresponding metal concentrations in ash fill samples. These results indicate that road bed, soil stockpile and pond sediment samples do not consist of ash.

The following conclusions were developed based on our review of construction documents and our geotechnical investigation at the Site:

- The ash fill thickness was observed ranging 15.2 feet to 17.2 feet in the 3 test borings. Relative compaction results for ash fill at the three test pit locations ranged from 84 to 92%.

- Based on the tests MACTEC performed on the ash fill and our review of the construction documents, it can generally be confirmed that compactive energy was applied to the ash fill when placed. The degree of compaction at placement was not quantified from the results of this assessment due to potential post-placement expansion and changes in moisture content.

- Soil cover thicknesses of less than 18 inches were encountered in two general areas of the Site. MACTEC understands that cover in these areas will be restored to a minimum of 18 inches. Soil cover generally consisted of clayey silt and clayey, fine-grained sand.

- Ash fill analyses were reportedly inconclusive in determining the kiln dust (amending agent) content in the three ash fill samples collected from the Site. The laboratory results indicated evidence of higher calcium oxide concentrations by weight in the ash fill samples than in the ash standard, which may indicate the presence of a calcium amendment, although the percentage of kiln dust was not confirmed.

- In general, and subject to additional confirmatory sampling, our findings at the Site do not presently indicate adverse impact to groundwater from the placement of ash.