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PPRP

Hydrogeologic Study of the Piney Branch Bog Watershed
Charles County, Maryland

September 2009

MARYLAND POWER PLANT RESEARCH PROGRAM

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Hydrogeologic Study of the Piney Branch Bog Watershed

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September 2009

FOREWORD AND ACKNOWLEDGEMENTS

This report was prepared under the direction of Sandra Patty at the Maryland Department of Natural Resources, Power Plant Research Program (PPRP). Under contract to PPRP, the following individuals were responsible for conducting the work associated with this environmental review:

- Matthew Erbe, P.G., and Robert Keating, P.G., Environmental Resources Management, Inc., Annapolis, MD, under Contract #K00B0200092.

We would like to acknowledge the assistance of Deborah Landau, Ph.D., of The Nature Conservancy for participating in the study design and review of the report.

ABSTRACT

This document summarizes ERM's evaluation of the Piney Branch Bog in Charles County, Maryland. On behalf of the Maryland Department of Natural Resources (MDNR) Power Plant Research Program (PPRP) and The Nature Conservancy, Environmental Resources Management, Inc. (ERM), as the Environmental Engineering Integrator (EEI) for PPRP, has conducted a field study to characterize the pre-development hydrology of the Piney Branch Bog and establish baseline hydrologic conditions in the water table aquifer.

Study objectives included characterizing the stratigraphy; determining depth and water flow direction; quantify the amount of water that discharges into the bog over time; and establishing a baseline for the ground water quality in the bog.

Information generated through short and long-term ground and surface water monitoring events, and water budget analysis have been used to fulfill the study objectives and develop a ground water flow model calibrated to the Piney Branch Bog hydrology. In the future, the model may be used to assess development impacts and to develop guidelines for ensuring the long-term health of the bog.

The study's findings relating to the stratigraphy, water table, water quantity, and water quality of this bog indicate relatively good ecological health; however, the rapid development of the surrounding area could alter the unique characteristics of the hydrologic system that are required to support the bog ecology.

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1.0 INTRODUCTION

Piney Branch Bog is an approximately three-acre scrub-shrub wetland located within a tributary of Zekiah Swamp on the Coastal Plain of Maryland in Charles County. A unique Maryland ecological feature, the bog is currently the only known example of a "gravel bog" in the state (Meadowview, 2000). Piney Branch Bog is also the only known Maryland habitat for the globally-rare New Jersey Rush and one of the few sites in the state for the Purple Pitcher Plant (and likely the farthest western occurrence of this plant in Maryland).

Bogs are very acidic, nutrient-poor, low-oxygen systems and possess a suite of vegetation that thrives under these conditions. Gravel bogs possess a relatively shallow layer of organic substrate that overlay a thick layer of coarse gravel. The base vegetation that drives this system is sphagnum mosses. The sphagnum grows in a dense mat throughout most of the bog, trapping water and breaking down into organic material through anaerobic processes. Although technically a misnomer, the term bog as applied here has conventionally been used to describe an acidic, sphagnum wetland that strongly bears a resemblance to bogs (Simmons, Strong and Tice, 2003). Piney Branch Bog is actually an acidic, fen-like seep in that a large part of the bog is supplied by steady ground water seepage from the surrounding gravel deposits.

The watershed that provides recharge to Piney Branch Bog is approximately 62 acres. The majority of the watershed has long been unimproved; however, current plans for development over a large portion of the watershed are underway. Prior to the investigation, Charles County began grading land to allow for the widening of Billingsley Road where it passes through the watershed. Construction of the additional lanes was initiated in the summer 2007. In December 2007, CPV Maryland, LLC submitted an application to the Public Service Commission (PSC) to construct and operate a nominally rated 640 megawatt combined-cycle natural gas-fired power generating station and associated facilities at the Piney Reach Business Park. The footprint for the 76-acre facility is identical to that of the Kelson Ridge Project, a 1,650 megawatt gas-fired electric generating facility that received a Certificate of Public Convenience and Necessity (CPCN) in September 2001, but was never constructed due to unfavorable market conditions. The CPV St. Charles project was awarded a CPCN by the PSC in November 2008.

The quantity and poor quality of storm water discharges (i.e., nutrient and sediment loads) from the current and proposed development may result in the destruction of the hydrologic system supporting the sphagnum based wetland, and the associated flora and fauna.

1.1 PURPOSE & OBJECTIVES

On behalf of the Maryland Department of Natural Resources (MDNR) Power Plant Research Program (PPRP) and The Nature Conservancy, Environmental Resources Management, Inc. (ERM), as the Environmental Engineering Integrator (EEI) for PPRP, has conducted a field study to characterize the pre-development hydrology of the Piney Branch Bog and establish baseline hydrologic conditions in the water table aquifer. The primary objectives of the study were:

1. Characterize the stratigraphy (i.e., layers of sediments) of the water table aquifer in the watershed;
2. Determine the depth of the water table and the direction of ground water flow in the water table aquifer over time;
3. Quantify the amount of water that discharges into the bog over time; and
4. Establish a baseline for the ground water quality in the bog watershed.

Information generated through short and long-term ground and surface water monitoring events, and water budget analysis have been used to fulfill the study objectives and develop a ground water flow model calibrated to the Piney Branch Bog hydrology. In the future, the model may be used to assess development impacts and to develop guidelines for ensuring the long-term health of the bog.

The field investigation to complete this hydrologic study was performed in accordance with ERM's Scope of Work presented to PPRP on 30 June 2003. ERM's Scope of Work was prepared to facilitate characterization of the bog as part of PPRP's review of potential impacts to environmental receptors adjacent to the formerly proposed location once considered for the Kelson Ridge Power Plant.

1.2 REPORT ORGANIZATION

This report is divided into the following sections:

- Section 2.0 – Environmental Conditions describes the site location, topography, climatology and regional hydrogeology for the study area;
- Section 3.0 – Site Characterization presents the subsurface stratigraphy, ground water flow conditions, water quality analyses, and water budget analysis for the study area;
- Section 4.0 – Ground Water Flow Model describes the setup and results of the hydrogeologic model for the bog;
- Section 5.0 – Summary of Findings provides the key findings of the investigation; and
- Section 6.0 –Recommendations proposes mitigation measures which can be developed to maintain stability of the Piney Branch Bog area and guidelines for long-term maintenance of the bog.

2.0 *ENVIRONMENTAL CONDITIONS*

2.1 *LOCATION AND TOPOGRAPHY*

Piney Branch Bog is located at approximately 38° 34' 15" North, 76° 53' 45" West, approximately 5 miles northeast of La Plata in Charles County, Maryland (Figure 1). The bog is almost entirely situated within the Potomac Electric Power Company (PEPCO) transmission line right-of-way (ROW) on the south side of Billingsley Road. The overall site topography is a level upland area incised by the stream valleys of tributaries to Piney Branch and Zekiah Swamp with land surface elevations within the watershed ranging from 175 to 225 feet above mean sea level (Figure 1).

2.2 *CLIMATE*

Normal climate data for the study area was obtained from the National Climatic Data Center Cooperative Network Station 185080 in LaPlata (NCDC, 2002). Charles County has a temperate climate, affected to some degree by the proximity of the Potomac River and Chesapeake Bay. Situated in the mid-Atlantic, the area has four well-defined seasons. The frost-free growing season typically occurs from late April to late October. The normal range of mean monthly temperatures is 40.8 Fahrenheit degrees (°F) between the warmest month, July (75.8 °F), and the coolest month, January (35.0 °F) (NCDC, 2002). The prevailing wind pattern is from the northwest during October to April and from the south and southwest from May to September. Mean annual rainfall for the area is 44 inches; although the last six years have averaged more than 48 inches of rainfall. Average annual snowfall is approximately 17 inches (roughly equivalent to 1.7 inches of rainfall).

2.3 *SOILS*

Soil unit descriptions have been collected from the *Soil Survey of Charles County, Maryland* compiled by the USDA Soil Conservation Service (USDA SCS, 1974). The soils which make up a majority of the 62 acre watershed are the Mattawan Loamy Sand (53 percent) and the Evesboro Loamy Sand (30 percent). The remainder of the surficial materials in the watershed consists of the Gravelly Sand (10 percent) and the Bourne Sandy Loam (7 percent) (USDA SCS, 1974).

- Mattawan Loamy Sand (Ms) – This unit is found in the northern most half of the watershed, isolated from the stream and the bog, and is the most suitable land for development. The unit consists of moderately well to well drained soils with a nearly level to gently sloping land surface, totaling a depth of approximately 60 inches. The soils are very strongly acidic and friable near the surface, grading to extremely acidic and slightly plastic at depth. In general, the Ms unit grades from light brownish-grey sand near the surface to a light brownish-grey sandy loam, and eventually a mottled yellow, brown and grey sandy clay loam at the base of the unit. The gradation from a sandy loam to a clay loam denotes a decrease in hydraulic conductivity with depth, indicating the presence of a shallow water table during periods of moderate to heavy precipitation.

- Evesboro Loamy Sand (EvB) – This unit consists of very deep, excessively drained, level to moderately sloping soils, totaling a depth of approximately 60 inches. The soils are strongly acidic, grading to extremely acidic at the base. The soils grade from loose and very friable at the surface, to loose at the base. The EvB unit grades from a fine-grained brown loamy sand at the surface, to a yellowish-brown loamy sand, and eventually a yellowish-brown gravelly loamy sand at the base of the unit. The EvB unit can be found outlying the gravelly land near the stream. Hydraulic conductivity is high throughout the EvB unit, indicating in general a deeper water table than the Ms soil unit.

- Gravelly Land (GvE) – This unit consists of gravelly deposits of eroded soil material. The gravelly deposits can be found at the southeastern edge of the watershed, near the source of the only stream in the watershed. These gravelly deposits have an extremely high permeability allowing water to infiltrate quickly into the subsurface. Recharge within the watershed and the impermeable underlying clay of the Brandywine Formation allow for high volumes of ground water to flow relatively continuously through these gravelly deposits. The water within the GvE unit supports the growth of sphagnum moss above the gravel, which creates a unique environment for Piney Branch Bog.

- Bourne Sandy Loam (BrC2) – This unit consists of gently to moderately sloping (5 to 10 degrees), moderately well drained soils which have been moderately eroded. This unit can be found on the far eastern section of the watershed.

2.4 *REGIONAL HYDROGEOLOGY*

The surficial sediments that overlie the majority of the Charles County landscape are mapped by the Maryland Geological Survey as the Upland Deposits (McCartan, 1989). The Upland Deposits have also been referenced as including the Brandywine, Bryn Mawr and Sunderland Formations (Wilson, 1986). The Upland Deposits in Southern Maryland range from 0 to roughly 50 feet in thickness and contain significant amounts of orange-brown gravel and sand with minor amounts of silt and red, white, or grey clay, a lower gravel member, and an upper loam member (McCartan, 1989). The sediments are derived primarily from siliceous rock (i.e., quartz, quartzite, sandstone) that is very much resistant to weathering, both physical and chemical. These sediments also lack alkaline minerals such as calcium and magnesium which result in the acidic nature of the soil.

The unconfined water table is present in the sand and gravel layers of the Upland Deposits at depths of 0 to 30 feet beneath the ground surface (Slaughter and Otton, 1968). The water table aquifer ranges in thickness from approximately 10 to 40 feet and is separated from the underlying Aquia aquifer by more than 250 feet of confining clay and silt in the Calvert and Nanjemoy Formations, and the Marlboro clay. Most of the precipitation that falls on the watershed goes directly to streams as overland flow or is lost to the atmosphere and/or plant uptake by evapotranspiration. An much as 20 percent of precipitation recharges the regional water table aquifer (Slaughter and Otton, 1968).

Prior to this investigation, site-specific data had not been generated to empirically define the direction of shallow ground water flow. However, review of land surface topography (Figure 1) and direction of stream flows indicate that ground water flow directions likely follow a regional east to southeast trend through the Piney Branch Bog.

3.0 SITE CHARACTERIZATION

The headwaters of Piney Branch Bog are situated within a 7.6-acre parcel owned by the MDNR. The majority of the bog lies within a PEPCO transmission line ROW and extends onto property to the east owned by a local land developer. As a result, only about 75 percent of the bog and approximately 35 percent of the 62-acre watershed was accessible for conducting the study.

Hydrologic characterization of the Piney Branch Bog was evaluated through examination of soil boring cores, collection of ground water levels and water quality samples from piezometers, collection of surface water elevations, flow rates, and water quality samples, and monitoring of climatological data. Field activities were initiated in January 2005 and concluded in August 2007.

The following sections describe the equipment and methods utilized for the characterization of the bog.

3.1 STRATIGRAPHY OF THE WATER TABLE AQUIFER

Physical characteristics of sediments within the water table aquifer were determined through examination of soil cores collected during installation of temporary piezometers. Soil borings were completed between 9 and 28 feet below ground surface (ft bgs) and visual observations of color, texture, structure and moisture content were recorded (Appendix A).

In general, the upland areas of the Piney Branch watershed are capped by unconsolidated Coastal Plain deposits consisting of orange-tan, silty, fine to very coarse sands and gravels, and yellowish to orange silty-clay. During drilling activities within the Coastal Plain deposits, the unconfined ground water table was encountered within a sand and gravel layer that underlies and surrounds the bog. Cross sectional views (Figure 2A and 2B) illustrate the stratigraphy of the shallow soils in the study area and the position of the water table within the permeable coarse sand and gravel layer within the bog.

At the far western portion of the study area (boring B-8), approximately 15 feet of firm, dry clay was present beneath the ground surface. In the north (boring PZ-6) and western (PZ-7) reaches of the study area, the clay layer thins exposing the underlying silty-sands and gravels. The thickness of the silty-sand unit ranges from is 1 to 9 feet and is generally greatest north of Billingsley Road and at the upper elevations within the watershed study area.

Within the immediate vicinity of the bog, gravel and medium-grained sand predominates with little to no fine-grained sand, silt or clay. At the base of this unit, sediments increase in grade to poorly-sorted cobbles and gravel. There are numerous exposures of the gravel unit throughout the central portion of the study area. Beneath the gravel and cobble is a relatively dense and impermeable red/orange silty-clay consistent with descriptions of the Brandywine Formation (MGS, 1986). This clay overlies the more extensive Calvert Formation; a regional aquitard which significantly impedes vertical ground water flow.

3.2 GROUND WATER & SURFACE WATER FLOW CONDITIONS

Piezometers (PZ-1 through PZ-7) and stream gauges (SG-N1, N2, N3 and N4, SG-E1 and SG-E2) were installed in the study area to evaluate the relationship between surface water and ground water. Appendix A details the piezometer construction summarized in Table 1. The surficial, dry, dense clays which confine the water table aquifer in the western most portion of the study area prevented installation of a piezometer at the B-8 boring location.

Three Leveloggers® (constant water level and water temperature data logger), one Barologger® (barometric pressure and air temperature data logger), and one tipping-bucket rain gauge (RG-1) were installed at targeted locations within the Piney Branch Bog to provide continuous monitoring of precipitation and water level. Precipitation data was supplemented with data reported for nearby Andrews Air Force Base. Two Leveloggers® were installed in wells PZ-1 and PZ-3 to record short-term changes in the ground water table elevation as a result of precipitation events. The remaining Levelogger® was placed in the vicinity of PZ-1 at stream gauge SG-N2 to record changes in surface water elevation. Data was collected using the Leveloggers® and Barologger® at 15 minute intervals.

3.2.1 Water Table Elevation and Flow Direction

To facilitate the determination of the ground water elevation, piezometers were surveyed by a Maryland-licensed land surveyor for horizontal location and vertical elevation for the top of pipe relative to mean sea level. Water levels were measured manually on a monthly basis to evaluate variations in the water table. Specifically, water level measurements were collected on 3 March, 22 April, 23 May, 23 June, 20 July, 26 August, 1 September, 13 October and 6 December 2005; 23 February, 7 April and 15 May 2006; and 28 January and 22 August 2007.

During monthly water level monitoring events, water levels were measured at each monitoring well and stream gauge and used to determine ground and surface water elevations. Summary information gained from the monthly water level monitoring events is presented in Table 1. From these measurements, water table contours were developed for 22 April 2005 and 13 October 2005 (Figures 3 and 4, respectively). The three months preceding the April event had 12.23 inches of rainfall with 2.14 inches occurring two days prior to the event. The three months preceding the October event received 7.74 inches of rainfall with more than half of that amount (4.48 inches) occurring seven days prior to the monitoring event.

Curvature of water table (Figure 3 and 4) contours from April and October 2005 are indicative of wet season and dry season variations in ground water contributions to the surface streams within the bog. Specifically in April 2005, the contours curve in towards the upstream end of the stream channel indicating the discharge of ground water to the primary stream channel. Less curvature in the water table contours for October 2005 indicate that ground water is essentially flowing through the bog with little interaction or discharge to the stream channels.

3.2.2 Hydraulic Conductivity of the Water Table Aquifer

Single-well drawdown tests were performed on selected (PZ-1, PZ-2, PZ-3 and PZ-5) piezometers to assess the hydraulic conductivity of the water table aquifer. Reduction and analysis of data collected during the drawdown tests was performed using the Wilson, Cho, Beck and Vardy (1997) method for unconfined aquifers.

Prior to conducting the test in each well, the static water level was measured using an electronic water level indicator. The single-well drawdown tests were then performed by pumping the well through a fixed drawdown interval and recording the equilibrated flow rate. Specific capacity was calculated in milliliters per second per centimeter of drawdown. The specific capacity was multiplied by an empirical calibration factor, α, to estimate hydraulic conductivity in centimeters per second (cm/sec). The empirical calibration factor, α, was calculated as follows:

$$\alpha = [1 + \ln (z/2r_w)]/2\pi z \quad (1)$$

Where:

z is the screened interval below the water table; and

$2r_w$ is the outer diameter of the well borehole.

The hydraulic conductivity values calculated from the single well tests are summarized in Table 2. The average (arithmetic mean) hydraulic conductivity of 2.6 x 10^{-3} cm/sec (7.3 feet/day) falls at the lower range of 1 x 10^{-3} to 1 cm/sec published for well graded silty-sands and gravel (Fetter, 1994; Freeze and Cherry, 1979).

The average linear ground water velocity is the rate at which ground water moves between two points. The average linear velocity of ground water in the study area was calculated using the following equation:

$$v_e = (K_h \times \Delta h/\Delta l) / n_e \quad (2)$$

Where:

v_e is the effective ground water velocity (L/T);

K_h is the hydraulic conductivity (L/T);

$\Delta h/\Delta l$ is the hydraulic gradient (dimensionless);

and n_e is the effective porosity (dimensionless).

In the vicinity of the bog for example, using site-specific values for hydraulic gradient of 0.02 (Figures 3 and 4), an average hydraulic conductivity of 2.6 x 10^{-3} cm/sec (7.3 feet/day), and an estimated effective porosity of 0.30 for sand and gravel, the average linear ground water velocity in the gravel beneath the bog is approximately 175 feet/year. Further upgradient in the study area the hydraulic gradient of the water table decreases to about 0.005 indicating much lower ground water velocities than those within the gravel of the bog.

3.2.3 *Ground Water & Surface Water Interaction*

To evaluate the interaction of surface and subsurface water within the bog, water levels, stream flow rates, and precipitation events were monitored and compared. Surface water flow into the central portion of the bog was measured using a notched weir (W-1) on the down gradient side of the utility road along the PEPCO transmission line corridor. All surface water west (upgradient) of the road is channeled through a corrugated pipe running beneath the utility road and into the bog.

Continuous water level measurements were collected at piezometer PZ-1 and stream gauge SG-N2, and normalized for changes in barometric pressure. Collection of rainfall data from the on-site rain gauge (RG-1) was limited to the period 23 June 2005 through 13 October 2005 (as a result of vandalism); the data was supplemented with precipitation data recorded by the NOAA weather station at Andrews Air Force Base (AAFB). In general, ground water levels at PZ-1 and surface water flows at SG-N2 had a high correlation during the June through October 2005 monitoring event (Figure 5) while increases in ground water and stream flow rates are observed with increased precipitation. Due to malfunctions with the data logging electronics, no records were recorded from 21 July through 31 August for PZ-1 and from 8 August through 31 August for RG-1.

To evaluate the correlation of surface water flow to ground water levels, periods of high and low rainfall were compared (Figure 6). Between 1 October and 6 October 2005, the study area received less than 0.3 inches of rainfall while during 7 and 8 October nearly 6 inches of rainfall was recorded. During the 0.3 inch precipitation event, both surface water and ground water elevations declined (Figure 6). Within a few hours of the 6 inch rainfall event, the surface water elevation began to rise with a lag time in rising ground water elevations. This behavior indicates that under dry conditions, surface water flow in the bog responds more quickly to rainfall than does ground water elevations. During the period immediately following the 6 inch rainfall event, both ground and surface water elevations continued characteristically increasing trends while returning to post-rainfall levels within a few hours of the end of precipitation.

3.3 WATER BUDGET ANALYSIS

The ground water elevation data indicate that the bog is substantially maintained by ground water seepage into the system. During the warmer and dryer months of July through October, the bog is likely recharged by precipitation infiltrating through the vast expanse of gravel exposed in the upland areas of the watershed.

Hydrologic cycles are commonly expressed quantitatively in terms of a water budget equation. The water budget accounts for gains and losses in an area for a selected period of time. To better understand the accounting of water in the system, a water budget was prepared for the bog. The water budget equation is written:

$$P = I + R + ET + \Delta S \quad (3)$$

where:

P equals annual precipitation (i.e., rainfall and snow);

I is infiltration (i.e., water available as aquifer recharge);

R is runoff (i.e., water that flows overland to streams);

ET is total evapotranspiration (i.e., water that is evaporated from the surface or is used by vegetation); and

ΔS is change in basin storage (i.e., results in an increase or decrease in the average water table elevation).

For the study area drainage basin the term P was measured and the terms I, R, ET and ΔS were estimated based on literature values and site conditions as described below. Climatic data were obtained from NCDC LaPlata 1W weather station for the period from 1971 to 2000, described in Section 2.2 above. Relatively close to the study area, the LaPlata weather station is believed to represent very similar climatic conditions within the study area.

Reviews of aerial photography indicate that over 90 percent of the study area is forested, and the remaining 10 percent is used for agricultural purposes (e.g., soybean and rotational crops). As discussed in Section 2.0, soils in the study area predominantly consist of gravelly loamy sand to sandy clay loam. These soils have a high infiltration rate and relatively low storm runoff rates. The NRCS classifies these soils as type "B" (e.g., sandy loam and loam) soils with an estimated (MDE WMA, 1997) average annual recharge of 12 inches per year. Accordingly, total infiltration was estimated as 12 inches per year based on the areal extent of soils at the site.

The water balance method developed by Thornthwaite and Mather (1957) was used to determine the potential and actual amounts of evapotranspiration. The method uses infiltration factors to determine the fraction of water surplus that infiltrates into the ground and the fraction that runs off to nearby streams. The Thornthwaite and Mather method requires monthly precipitation, monthly temperature, and latitude of the site (to determine day length and solar heating amount), vegetation type, soil type, and a series of tables. The tables define a heat index, potential evapotranspiration, water holding capacity, and soil moisture retention. Snowfall and alternating wet and dry cycles are included. Soil water holding capacity is dependent upon the soil type, soil structure and the type of vegetation growing on it.

Using the data described above and the Thornthwaite and Mather (1957) method for determining the evapotranspiration and runoff, the estimated annual evapotranspiration for the bog watershed is approximately 30 inches or about 68 percent of the annual precipitation. Direct runoff to streams and the bog is about 2 inches per year. The water budget developed below assumed no change in the drainage basin storage (i.e., rise or fall of the water table).

Pre-Development Annual Water Budget Component Summary

Precipitation	Infiltration	Direct Runoff	Evapotranspiration
44.0 inches	12.0 inches	1.9 inches	30.1 inches
74.0 x 10^6 gallons	20.2 x 10^6 gallons	3.2 x 10^6 gallons	50.7 x 10^6 gallons

Note: Volumes are based on a 62-acre watershed.

3.4 BASELINE WATER QUALITY CONDITIONS

Three rounds of ground water and surface water quality samples in the bog watershed were collected. Two sampling events (27 July 2005 and 22 through 23 August 2007) were conducted during the dry season to evaluate baseflow conditions. The third (15 May 2006) round of samples was collected during the wet season. During 27 July and 15 May 2005, samples were collected from PZ-1 through PZ-7 as well as an upstream, midstream, and downstream point within the main stream channel that exits the bog. During 22 and 23 August 2007, ground water samples were not collected from PZ-1 or PZ-3 due to a lack of access. Additionally, the down gradient surface water sampling location was inaccessible and the upgradient location was dry (i.e., baseflow conditions prevailed).

Ground and surface water samples were analyzed for the following constituents:

1. Inorganic trace elements, consisting of antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc;

2. Volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), organochlorine pesticides, and selected herbicide compounds[1];

3. Major cations, consisting of aluminum, calcium, iron, magnesium, potassium, and sodium;

4. Major anions, consisting of chloride, fluoride, nitrate, nitrite, and sulfate; and

5. Alkalinity (with carbonate and bicarbonate calculation).

Water samples were also field screened for pH, temperature, specific conductivity, dissolved oxygen, and oxidation-reduction potential. Ground water samples submitted for analysis of inorganic trace elements were field filtered using a 0.45-micron filter. All samples were preserved following the sample method protocol. Results of analytical findings from sampling events are summarized in Tables 3A, 3B, and 3C and discussed in the following Sections.

For comparison purposes, Tables 3A, 3B, and 3C include freshwater screening benchmarks published by the United States Environmental Protection Agency (USEPA) Biological Technical Assistance Group (BTAG) (2008). These screening benchmarks are routinely used as a preliminary way of assessing the potential for biological, chemical or physical stressors to affect ecosystems. Such stressors might occur in the natural environment at densities, concentrations or levels high enough to disrupt the natural biochemistry, physiology, behavior and interactions of the living organisms that comprise freshwater environments. Metals and other inorganic substances are naturally found in the environment, and therefore, the use of BTAG screening benchmarks provides an initial indication of water quality conditions. An assessment of ecological risk is beyond the scope of this report.

3.4.1 Ground Water Quality

VOCs, SVOCs, PCBs, pesticides, and herbicides were not detected in any of the ground water samples during any of the sampling events. Of the dissolved inorganic trace elements, barium, manganese, and zinc were

[1] Samples collected during the August 2007 sampling event had a shortened list of analytes.

detected in ground water during all three of the sampling events. Only manganese was consistently reported slightly above the MDE standard of 0.05 mg/l. Several other inorganic trace elements were detected at low concentrations, including cobalt, copper, nickel, and silver. More inorganic trace elements were detected during the wet season sampling event (May 2006) than in either of the dry season sampling events. This suggests that increased precipitation and, consequently, increased infiltration of water through the bog leads to a notable difference in ground water chemistry.

Based on pH readings collected in the field, ground water in Piney Branch Bog is acidic. pH during the different sampling events ranged from 4.50 to 5.10 in July 2005, 4.19 to 5.09 in May 2006, and 4.29 to 5.33 in August 2007. Ground water is consistently more acidic during the wet season at all piezometer locations except PZ-2, which had a slightly lower pH in August 2007 (5.02) than in May 2006 (5.07).

Ground water chemistry parameters collected during the three sampling events indicate that major cations in ground water at the site are primarily sodium and potassium, although calcium and magnesium are also consistently present. Chloride and sulfate are the predominant anions. Bicarbonate was rarely present above a detection limit of 10 mg/l. Levels of these parameters also tended to be higher during the wet season in most cases. However, PZ-5 varied slightly from this, as the level of calcium steadily increased from 4.0 mg/l in July 2005, to 5.4 mg/l in May 2006, to 7.1 mg/l in August 2007.

3.4.2 *Surface Water Quality*

As with ground water, VOCs, SVOCs, PCBs, pesticides, and herbicides were not detected in any of the surface water samples during any of the sampling events. Also similar to the ground water results, dissolved inorganic trace elements detected in surface water during each sampling event included barium, manganese, and zinc. Cobalt, copper, lead, nickel, and vanadium were also detected at low concentrations during the May 2006 wet season sampling event.

pH readings collected in the field indicate that surface water in the unnamed tributary that flows through Piney Branch Bog is slightly less acidic than ground water. Readings taken during the May 2006 sampling event ranged from 4.76 to 5.45. Field pH readings were not collected in July 2005, and only one surface water sample was collected in August 2007 due to accessibility issues and dry conditions.

Comparison of the seasonal results indicates that the surface water in Piney Branch Bog overall has similar chemistry from dry to wet season, particularly with respect to anthropogenic organic compounds. However, the increased number of inorganic compounds during the wet season, May 2006, sampling event does suggest a potential for impacts to the bog to occur as a result of storm water runoff from the road surface. The highest concentrations of cations and trace metal compounds detected during this event were at the SG N1 location, which is closest to a storm water outfall on the south side of Billingsley Road.

4.0 GROUND WATER FLOW MODEL

A two-dimensional ground water flow model was developed as a tool to assess the potential impact of future development within the watershed on the Piney Branch Bog. Based on modeling scenarios, measures could be established to mitigate adverse impacts and develop guidelines for assuring the long-term health of the bog.

The site is situated near the contact of the Upland Deposits and Miocene clay ("Calvert Clay") within the Calvert Formation. The surficial Upland Deposits consist of coarse sands and gravels with a maximum thickness of 50 feet and a thickness of approximately 25 feet at the bog. Most surface streams that receive ground water discharge within the watershed are incised within the clay of the Calvert Formation.

For model development, the conceptual model consisted of two horizontal layers representing the Upland Deposits and the underlying Calvert Clay with surface streams receiving ground water discharge, and the entire watershed received infiltration recharge from precipitation.

4.1 MODEL SETUP

The ground water flow model for the Piney Branch Bog watershed was constructed using TWODAN (Fitts, 1997), an analytic element model. The model extends to natural hydraulic boundaries (flow divides) surrounding the study area. Covering an area of 6.5 square-miles (Figure 7), the model includes all watershed features impacting the ground water flow system within the bog. The model simulates the water cycle starting from precipitation infiltration to ground water flow through the aquifer to ground water discharge to the nearby streams which were monitored for stream flow rates.

The model consists of two layers representing an upper Upland Deposit layer and a lower Calvert Clay layer. Because the model simulates water table elevations, areas of Upland Deposit conductivity values were subdivided into areas where the water table is within the stream valley areas of the Upland Deposits and Upland plateau areas where the water table falls within a more permeable sand and gravel layer (Figure 8).

For model calibration, the simulated average surface water discharge at (weir) W-1 was fixed based on the collected field data for that location.

Also, hydraulic conductivity values for the Upland Deposits were fixed for areas of the watershed where conductivity values calculated from field tests were available. The values of conductivity for the Upland Deposits within the Upper plateau area and the Calvert Clay, and the recharge rate were varied within an acceptable range to achieve a reasonable match of simulated to observed ground water levels.

Following the ground water modeling guidelines developed by the American Society for Testing and Materials (ASTM, 1994), the predetermined model calibration criteria were used for the model calibration:

- The average of the residuals (difference between model calculated and observed water levels) is less than 2 percent of the natural water level variation difference, and
- The standard deviation of the residuals is less than 10 percent of the natural water level variation difference.

Because the model simulates average or steady-state conditions, the average ground water levels observed over the period of record was used for the resulting model calibration. The final model parameters (Table 4) were based on a combination of the available observed data, field derived estimates of aquifer parameters, an understanding of the site stratigraphy, and a good statistical match of simulated to average of observed water levels (Table 5).

For the resulting model calibration (Table 5), the mean of the residuals for the average flow condition is 0.01 feet, which is 0.1 percent of the natural water table difference of 6.86 feet. This average residual is much less than the 2 percent ASTM guideline. The standard deviation of the residuals (0.31 feet) is 4.5 percent of the natural water level variation which is well within the ASTM criteria of 10 percent.

Although the simulated (8.6 in/yr) recharge rate is somewhat less than the water budget analysis (Section 3.3) value of 12 in/year, the simulated value represents an average value over the period of available water level records at the site. Calibrated conductivities for the Calvert Clay and the Upland plateau surficial sand and gravel deposits are well within the ranges of acceptable published values (e.g., Fetter, 1994).

Based on calibration statistics and a favorable comparison of the calibrated model parameters with field conditions, the model is considered appropriate for predictive simulations. Due to the relatively good calibration and the incorporation of empirical site data, the model has a reasonably high degree of confidence for predicting the potential impact of future land development scenarios.

4.2 MODEL RESULTS

Simulated ground water levels and flow directions (Figure 9) indicate that the ground water flow from upgradient areas travels radially towards surface streams along the outer fringe of the watershed. Similar to the more than ten streams in the watershed, the small stream in the vicinity of the bog receives ground water discharge. The ground water velocity in the Upland Deposit plateau is relatively high due to the conductive coarse gravels which become exposed in the vicinity of incised streams that include the Piney Branch tributary within the bog. The relatively low conductivity of the Calvert Clay creates a much higher ground water gradient adjacent to portions of streams incised within the clay compared to the relatively low hydraulic gradients adjacent to streams incised within the highly permeable Upland Deposit sand and gravel.

Modeling results indicate that ground water enters the stream and bog from the northwest. As noted, the bog is situated in the transition zone between the Upland Deposits and the underlying Calvert Clay. At the lower reaches of the bog, the surface stream has deeply incised the Calvert Clay creating relatively steep side slopes and exposing the gravel layers that have been eroded and deposited from the Upland plateau areas. The relatively fast moving water within the bog is due to a corresponding high rate of ground water discharge through the highly permeable Upland Deposit sands and gravel in the area of the Upland plateau.

Existing and future land development will inevitably alter the ground water flow dynamics and the delicate ecological balance within and surrounding the Piney Branch Bog. Adverse impacts can be caused by a number of activities including reduced infiltration by impervious surfaces, ground water flow alteration or blockage by highway and road construction, and storm water runoff. The ground water flow model was developed in anticipation of the development that is now occurring around the bog to evaluate future impacts and, more importantly, derive effective strategies to mitigate hydrologic impacts of the surrounding development.

5.0 SUMMARY OF FINDINGS

The Piney Branch Bog is a unique natural feature in the state of Maryland and relies on recharge infiltration from the surrounding watershed to support a delicate ecological balance of flora and fauna. This study developed the following findings that will help to preserve the health of the bog:

- Stratigraphy – Within the immediate vicinity of the bog, gravel and medium-grained sand predominates. Precipitation from Upland areas recharges the highly permeable sand and gravel surrounding the bog and provides the high rate and volume of ground water seepage necessary to support the bog ecosystem;
- Water Table - The water table depth in the vicinity of the bog is within 5 to 10 feet of the land surface. Wet periods (typically in the spring), result in shallow ground water discharging through the sand and gravel layer into the bog as well as the streams that drain the bog. During dry periods in the Fall, an insignificant amount of ground water table discharges into the bog and the associated streams;
- Water Quantity – Precipitation results in approximately 74 million gallons per year flowing into the bog. Of this total, 20 million gallons (27 percent) infiltrates into the aquifer system, 3 million gallons (4.3 percent) is surface runoff, and nearly 51 million gallons (68 percent) is lost to evaporation and plant transpiration; and
- Water Quality - Analytical results for VOCs, SVOCs, PCBs, pesticides, herbicides, dissolved metals, alkalinity, and anions indicate that the baseline water quality in the bog is sound and of good quality.

Currently, the bog is in good ecological health; however the rapid development of the surrounding area could alter the unique characteristics of the hydrologic system that are required to support the bog ecology.

6.0 RECOMMENDATIONS

The Piney Branch Bog relies on recharge infiltration and surface water filtration from upgradient areas of the watershed. To ensure the continued good health of the bog and minimize development impacts, the following recommendations should be considered.

- Establish Buffers – Establish a permanent 100 foot protective buffer around the Piney Branch Bog tributary of the Piney Branch and the associated wetlands. In the buffer areas, no vegetation clearing, earthwork or other disturbances should be allowed with the exception of silt fences as set forth in approved Charles County habitat protection plans. ERM understands that this requirement has been included as a Licensing Condition (No. 56b) within the CPCN for the CPV St. Charles project.
- Restrict Zoning – Restrictions should be placed on construction of buildings and impermeable ground cover that impedes infiltration of surface water and creates unimpeded and untreated storm water runoff within the upland watershed areas out side of the protective buffer to alleviate impacts to the Piney Branch Bog hydrologic system.
- Monitor – In light of the current and proposed development in the watershed, continue periodic monitoring of surface and ground water quality in the bog to evaluate changes that may adversely impact the bog. Stream and ground water elevations should be included in the monitoring to evaluate changes in the bog water balance.
- Species Inventory – Conduct periodic inventories of flora and fauna to determine if threatened or endangered species habitat has adversely impacted by surrounding development and if further enforced protection of the habitat is warranted.
- Simulate Impacts – Using the ground water model developed in this study, evaluate scenarios simulating the impact of various types (e.g., residential, commercial, open space, etc.) of development around the bog and in upland areas of the bog watershed.

Bogs and wetlands are areas of transition where the flow of water and the nutrients and sediments create unique ecosystems that support a wealth of plant and animal life. In addition to providing essential habitat for fish, birds, and other wildlife, bogs and wetlands provide valuable economic benefits, such as controlling floods and filtering pollutants. Institutional controls to mitigate impacts from surrounding development and periodic monitoring of ground and surface water will help to ensure the health of the unique features of the Piney Branch Bog.

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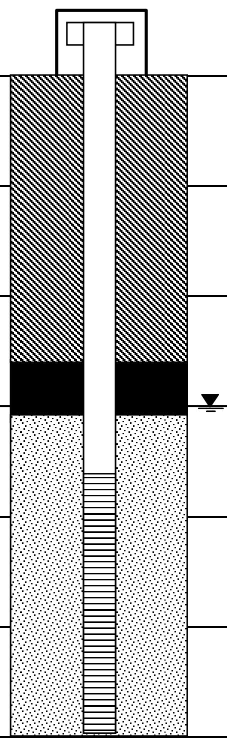
Appendix A
Soil Boring and Piezometer Construction Logs

Environmental Resources Management
Boring / Well Construction Log

Boring/Well ID: PZ-1

Site Name & Location:	Piney Branch Bog in Charles County, MD	Date & Time Started:	21 January 2005 1535
Project Number:	53545	Date & Time Completed:	25 January 2005 1425
Drilling Company:	Tidewater Drilling Services	Drilling Equipment:	Geoprobe® 6620 DT
Driller:	Stefan and Alfredo	Drilling Method:	Direct Push and Hollow Stem Auger
Reference Elevation & Datum:	186.72 ft amsl	North Coordinate:	329176.2
Ground Elevation & Datum:	Not Measured	East Coordinate:	1341963.3
Borehole Diameter:	8.25 inches	Well Diameter & Material:	2-inch PVC
Borehole Depth:	24 feet	Screen Slot Size:	0.020-slot
Sampler Type & Interval:	2" Macrocore®	Geologist (s):	Gavin Fielding



Depth (feet BGS): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28

Sample Interval #	Recovery (feet)	PID (ppm)	Laboratory Sample	Sample Description/Classification
		---	---	Dry, soft, very dark brown topsoil with organic matter.
		---	---	Dry, white-orange, coarse sand and gravel.
				Same as above.
				Same as above.
				Same as above.
		---	---	Dry, well sorted, cream, sub-rounded, coarse sand.
				Same as above.
		---	---	Dry, well sorted, bright orange sub-rounded, coarse sand.
				Same as above.
				Same as above.
		---	---	clayey sand.
		---	---	Moist/wet, gray, friable, subangular gravel.
				Same as above.
		---	---	Wet, cream gravel and silt with some fine sand.
				Same as above.
		---	---	Wet, homogeneous, orange silt/clay.
				Same as above.
				Same as above.
				Same as above.
		---	---	Wet, laminated, orange silt/clay with gray laminae.
				Same as above.
				Same as above.
				Same as above.
				Same as above.

Monitoring Well Construction Specifications

2" PVC above grade riser.

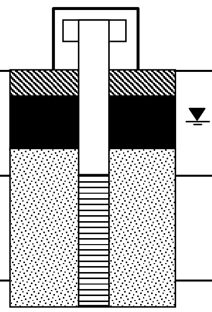
Riser Interval:	NA	-	24.0	feet bgs
Screen Interval:	14.5	-	19.5	feet bgs

Portland Cement Grout:	0.0-10.5	ft bgs
Hydrated Bentonite Chips:	10.5-12.5	ft bgs
#2 Morie sand Filter Pack:	12.5-24.0	ft bgs

Environmental Resources Management
Boring / Well Construction Log

Boring/Well ID: PZ-2

Site Name & Location:	Piney Branch Bog in Charles County, MD	Date & Time Started:	21 January 2005 1420
Project Number:	53545	Date & Time Completed:	21 January 2005 1530
Drilling Company:	Tidewater Drilling Services	Drilling Equipment:	Geoprobe® 6620 DT
Driller:	Stefan and Alfredo	Drilling Method:	Direct Push and Hollow Stem Auger
Reference Elevation & Datum:	184.05 ft amsl	North Coordinate:	329582.3
Ground Elevation & Datum:	Not Measured	East Coordinate:	1341963.3
Borehole Diameter:	8.25 inches	Well Diameter & Material:	2-inch PVC
Borehole Depth:	9 feet	Screen Slot Size:	0.020-slot
Sampler Type & Interval:	2" Macrocore®	Geologist (s):	Gavin Fielding



Depth (feet BGS)	Sample Interval #	Well Construction Schematic	Recovery (feet)	PID (ppm)	Laboratory Sample	Sample Description/Classification
				---	---	Dry, soft, very dark brown topsoil with organic matter.
2				---	---	Moist/wet, orange, medium sand and gravel and some friable clay.
						Same as above.
						Same as above.
4						Same as above.
6						Same as above.
						Same as above.
8						Same as above.
						Same as above.
10						
12						
14						
16						
18						
20						
22						
24						
26						
28						

Monitoring Well Construction Specifications

Steel-above-grade locked well cover with locking well cap inside of 2" OD piezometer.

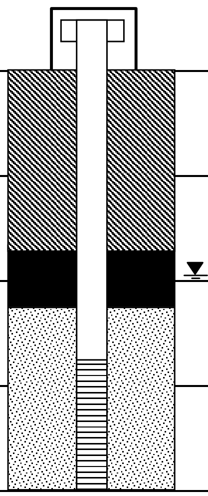
Riser Interval:	NA	-	4.0	feet bgs
Screen Interval:	4.0	-	9.0	feet bgs

Portland Cement Grout:	0.0-1.0	ft bgs
Hydrated Bentonite Chips:	1.0-3.0	ft bgs
#2 Morie sand Filter Pack:	3.0-9.0	ft bgs

Environmental Resources Management
Boring / Well Construction Log

Boring/Well ID: PZ-3

Site Name & Location:	Piney Branch Bog in Charles County, MD	Date & Time Started:	18 January 2005 1330
Project Number:	53545	Date & Time Completed:	19 January 2005 1045
Drilling Company:	Tidewater Drilling Services	Drilling Equipment:	Geoprobe® 6620 DT
Driller:	Stefan and Alfredo	Drilling Method:	Direct Push and Hollow Stem Auger
Reference Elevation & Datum:	190.01 ft amsl	North Coordinate:	329794.6
Ground Elevation & Datum:	Not Measured	East Coordinate:	1341842.3
Borehole Diameter:	8.25 inches	Well Diameter & Material:	2-inch PVC
Borehole Depth:	16 feet	Screen Slot Size:	0.020-slot
Sampler Type & Interval:	2" Macrocore®	Geologist (s):	Gavin Fielding



Depth (feet BGS)	Sample Interval #	Well Construction Schematic	Recovery (feet)	PID (ppm)	Laboratory Sample	Sample Description/Classification
				---	---	Dry, cream, coarse gravel and some coarse sand.
2				---	---	Dry, cream, coarse gravel and some orange-brown, coarse sand.
						Same as above.
4				---	---	Moist cream, medium sand and gravel.
						Same as above.
6				---	---	Dry, yellow, white, red variegated clay.
						Same as above.
8				---	---	Wet, cream, gravel.
						Same as above.
10				---	---	Very wet, cream, gravel and silt.
						Same as above.
12						Same as above.
						Same as above.
14						Same as above.
						Same as above.
16						Same as above.
18						
20						
22						
24						
26						
28						

Monitoring Well Construction Specifications

Steel-above-grade locked well cover with locking well cap inside of 2" OD piezometer.

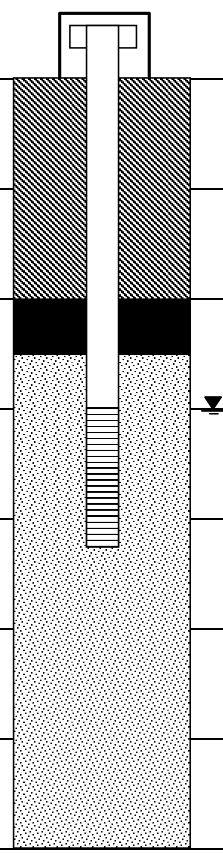
Riser Interval:	NA	-	11.0	feet bgs
Screen Interval:	11.0	-	16.0	feet bgs

Portland Cement Grout:	0.0-7.0	ft bgs
Hydrated Bentonite Chips:	7.0-9.0	ft bgs
#2 Morie sand Filter Pack:	9.0-16.0	ft bgs

Environmental Resources Management
Boring / Well Construction Log

Boring/Well ID: PZ-4

Site Name & Location:	Piney Branch Bog in Charles County, MD	Date & Time Started:	20 January 2005 1000
Project Number:	53545	Date & Time Completed:	21 January 2005 1345
Drilling Company:	Tidewater Drilling Services	Drilling Equipment:	Geoprobe® 6620 DT
Driller:	Stefan and Alfredo	Drilling Method:	Direct Push and Hollow Stem Auger
Reference Elevation & Datum:	192.06 ft amsl	North Coordinate:	329568.3
Ground Elevation & Datum:	Not Measured	East Coordinate:	1342137.9
Borehole Diameter:	8.25 inches	Well Diameter & Material:	2-inch PVC
Borehole Depth:	17 feet	Screen Slot Size:	0.020-slot
Sampler Type & Interval:	2" Macrocore®	Geologist (s):	Gavin Fielding



Depth (feet BGS)	Sample Interval #	Well Construction Schematic	Recovery (feet)	PID (ppm)	Laboratory Sample	Sample Description/Classification
				---	---	Dry, soft, very dark brown topsoil with organic matter.
2						Dry, white-orange gravel and sand.
						Same as above.
4				---	---	Same as above.
						Same as above.
6						Moist, orange, friable, fine to medium sand.
				---	---	Moist, orange, medium to coarse sand with some gravel and clay.
8				---	---	Dry, white-orange gravel and sand.
						Same as above.
10				---	---	Moist/wet, white-orange, friable gravel and sand.
						Same as above.
12				---	---	Wet, white-orange, friable gravel and sand.
						Same as above.
14						Same as above.
						Same as above.
16				---	---	Wet, white-orange, well sorted fine gravel.
						Same as above.
18						Same as above.
				---	---	Wet, orange, medium sorted, medium sand.
20				---	---	Wet, orange, gravel and friable clay.
						Same as above.
22						Same as above.
				---	---	Very wet, orange-gray, silt/clay.
24						(No recovery below this point due to moisture content.)
26						
28						

Monitoring Well Construction Specifications

Steel-above-grade locked well cover with locking well cap inside of 2" OD piezometer.

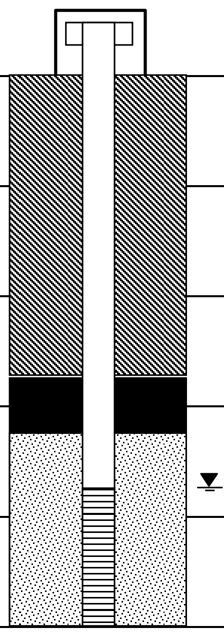
Riser Interval:	NA	-	12.0	feet bgs
Screen Interval:	12.0	-	17.0	feet bgs

Portland Cement Grout:	0.0-8.0	ft bgs
Hydrated Bentonite Chips:	8.0-10.0	ft bgs
#2 Morie sand Filter Pack:	10.0-17.0	ft bgs

Environmental Resources Management
Boring / Well Construction Log

Boring/Well ID: PZ-5

Site Name & Location:	Piney Branch Bog in Charles County, MD	Date & Time Started:	18 January 2005 0940
Project Number:	53545	Date & Time Completed:	18 January 2005 1300
Drilling Company:	Tidewater Drilling Services	Drilling Equipment:	Geoprobe® 6620 DT
Driller:	Stefan and Alfredo	Drilling Method:	Direct Push and Hollow Stem Auger
Reference Elevation & Datum:	191.80 ft amsl	North Coordinate:	329306.9
Ground Elevation & Datum:	Not Measured	East Coordinate:	1342235.7
Borehole Diameter:	8.25 inches	Well Diameter & Material:	2-inch PVC
Borehole Depth:	20 feet	Screen Slot Size:	0.020-slot
Sampler Type & Interval:	2" Macrocore®	Geologist (s):	Gavin Fielding



Depth (feet BGS)	Sample Interval #	Well Construction Schematic	Recovery (feet)	PID (ppm)	Laboratory Sample	Sample Description/Classification
				---	---	Dry, soft, very dark brown topsoil with organic matter.
2				---	---	Dry, orange, sand and gravel.
						Same as above.
4				---	---	Dry, white-orange, sand and gravel.
						Same as above.
6						Same as above.
						Same as above.
8				---	---	Dry, orange, medium sand and clay.
						Same as above.
10						Same as above.
				---	---	Dry, white-orange, sand and gravel.
12				---	---	Moist, orange, medium sand and clay.
				---	---	Moist, white-orange, sand and gravel.
14						Same as above.
						Same as above.
16				---	---	Wet, white-orange, sand and gravel.
						Same as above.
18				---	---	Wet, white-orange, sand and clay.
				---	---	Wet, white-orange, sand and gravel.
20						Same as above.
22						
24						
26						
28						

Monitoring Well Construction Specifications

Steel-above-grade locked well cover with locking well cap inside of 2" OD piezometer.

Riser Interval:	NA	-	15.0	feet bgs
Screen Interval:	15.0	-	20.0	feet bgs

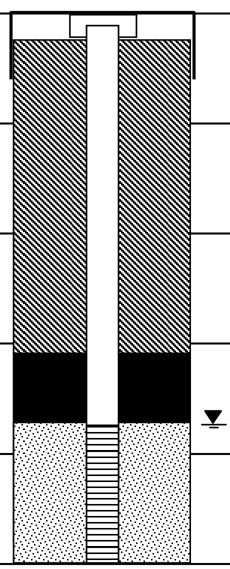
Portland Cement Grout:	0.0-11.0	ft bgs
Hydrated Bentonite Chips:	11.0-13.0	ft bgs
#2 Morie sand Filter Pack:	13.0-20.0	ft bgs

Environmental Resources Management
Boring / Well Construction Log

Boring/Well ID: PZ-6

Site Name & Location:	Piney Branch Bog in Charles County, MD	Date & Time Started:	16 February 2005 1000
Project Number:	53545	Date & Time Completed:	16 February 2005 1130
Drilling Company:	Tidewater Drilling Services	Drilling Equipment:	Geoprobe® 6620 DT
Driller:	Stefan and Alfredo	Drilling Method:	Direct Push and Hollow Stem Auger
Reference Elevation & Datum:	193.48 ft amsl	North Coordinate:	329983.7
Ground Elevation & Datum:	Not Measured	East Coordinate:	1342075.7
Borehole Diameter:	8.25 inches	Well Diameter & Material:	2-inch PVC
Borehole Depth:	20 feet	Screen Slot Size:	0.020-slot
Sampler Type & Interval:	2" Macrocore®	Geologist (s):	Adrian Hughes, V

Depth (feet BGS): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28



Sample Interval #	Recovery (feet)	PID (ppm)	Laboratory Sample	Sample Description/Classification
		---	---	Dry, soft, very dark brown topsoil with organic matter.
		---	---	Dry, orange, porous, peat/gravel, sandy silt.
				Same as above.
		---	---	Dry, loose, orange, cobbles.
				Same as above.
				Same as above.
				Same as above.
		---	---	Dry, loose, gravel and medium sand.
				Same as above.
				Same as above.
				Same as above.
		---	---	Dry, medium dense, medium sorted, medium sand.
				Same as above.
				Water.
				Same as above.
		---	---	Wet, medium sorted gravel with some medium sand.
				Same as above.
		---	---	Saturated, medium sorted gravel & sand with some silt.
				Same as above.
				Same as above.

Monitoring Well Construction Specifications

Steel, flush-mounted, locked well cover with locking well cap inside of 2" OD piezometer.

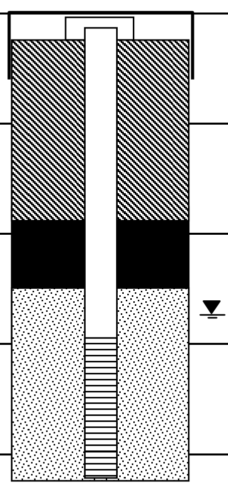
Riser Interval:	NA	-	15.0	feet bgs
Screen Interval:	15.0	-	20.0	feet bgs

Portland Cement Grout:	0.0-12.5	ft bgs
Hydrated Bentonite Chips:	12.5-15.0	ft bgs
#2 Morie sand Filter Pack:	15.0-20.0	ft bgs

Environmental Resources Management
Boring / Well Construction Log

Boring/Well ID: PZ-7

Site Name & Location:	Piney Branch Bog in Charles County, MD	Date & Time Started:	16 February 2005 1240
Project Number:	53545	Date & Time Completed:	16 February 2005 1345
Drilling Company:	Tidewater Drilling Services	Drilling Equipment:	Geoprobe® 6620 DT
Driller:	Stefan and Alfredo	Drilling Method:	Direct Push and Hollow Stem Auger
Reference Elevation & Datum:	190.82 ft amsl	North Coordinate:	329901.3
Ground Elevation & Datum:	Not Measured	East Coordinate:	1341119.6
Borehole Diameter:	8.25 inches	Well Diameter & Material:	2-inch PVC
Borehole Depth:	17.25 feet	Screen Slot Size:	0.020-slot
Sampler Type & Interval:	2" Macrocore®	Geologist (s):	Adrian Hughes, V



Depth (feet BGS)	Sample Interval #	Well Construction Schematic	Recovery (feet)	PID (ppm)	Laboratory Sample	Sample Description/Classification
				---	---	Dry, soft, very dark brown topsoil with organic matter.
2				---	---	Dry, orange, porous, poorly sorted cobbles, gravel, and sand.
						Same as above.
4				---	---	Dry, orange, medium dense, poorly sorted cobbles and gravel.
						Same as above.
6						Same as above.
						Same as above.
8				---	---	Moist, orange-brown, medium dense, poorly sorted gravel.
						Same as above.
10						Same as above.
						Wet.
12				---	---	Wet, orange-brown, poorly sorted, medium dense gravel.
						Same as above.
14						Same as above.
						Same as above.
16						Same as above.
						Same as above.
18						
20						
22						
24						
26						
28						

Monitoring Well Construction Specifications

Steel, flush-mounted, locked well cover with locking well cap inside of 2" OD piezometer.

Riser Interval:	NA	-	12.0	feet bgs
Screen Interval:	12.0	-	17.0	feet bgs

Portland Cement Grout:	0.0-7.75	ft bgs
Hydrated Bentonite Chips:	7.75-10.0	ft bgs
#2 Morie sand Filter Pack:	10.0-17.25	ft bgs

Environmental Resources Management, Inc.
Boring Log

Boring Number: **B-8**

Site Name & Location Piney Branch Bog in Charles County, MD	Project Number 53545	Date & Time Started Date & Time Completed	17 February 2005 0830 17 February 2005 1325
Drilling Company Tidewater Drilling Services	Driller Stephan/Alfredo	Sampler(s) 2" Acetate Liner	Sampler Depth 4' macrocore.
Drilling Equipment Geoprobe® 6620 DT	Method Direct Push	Ground Elevation & Datum 202.5 ft amsl	Completion Depth 20' / Rock Depth N/A
Bit Size 2" Macrocore (failed attempt to install well via HSA)	Core Barrel (s)	North Coordinate 330049.8	
Geologist(s) Adrian Hughes, V		East Coordinate 1339998.6	

DEPTH (ft below ground surface)	SAMPLES				SOIL DESCRIPTION	REMARKS
	Sample Number	Recovery (feet)	PID (ppm)	Lab Sample		
0	1	3.75	0.0	--	topsoil and surface cover.	
				--	Red, dry and very firm, dense mottled clay.	
2			0.0	--	Same as above.	
				--	Same as above.	
4	2	3.75	0.0	--	Same as above.	
				--	Same as above.	
6			0.0	--	Same as above.	
				--	Same as above.	
8	3	3.75	0.0	--	Same as above.	
				--	Same as above.	
10			0.0	--	Same as above.	
				--	Red, moist and firm, dense mottled clay.	
12	4	3.00	0.0	--	Same as above.	
				--	Same as above.	
14			0.0	--	Same as above.	
				--	Red and tan/orange, mottled silty clay with cobbles.	
16	5	2.50	0.0	--	Same as above.	
				--	Same as above.	
18			0.0	--	Same as above.	
				--	Same as above.	
20						

NOTES:

Water was not encountered in the boring. Clay thickness did not allow hollow stem auger techniques to penetrate below eight (8) feet below ground surface.

No piezometer was installed at this location.

Tables

Table 1. Piezometer, Stream Gauge, and Weir Construction and Water Level Summary

Monitoring Point ID	Construction Details				Water Level Monitoring														
	Borehole Depth	Piezometer Depth	Screen Depth	Piezometer Diameter	Measuring Point Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation
	(ft bgs)	(ft bgs)	(ft bgs)	(inches)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)
						3-Mar-05		22-Apr-05		23-May-05		23-Jun-05		20-Jul-05		26-Aug-05		1-Sep-05	
Piezometers																			
PZ-1	21.8	24	14.5-19.5	2	186.72	12.31	174.41	11.91	174.81	12.23	174.49	12.35	174.37	12.57	174.15	12.65	174.07	13.50	173.22
PZ-2	9.0	9	4.0-9.0	2	184.05	5.55	178.50	7.11	176.94	5.34	178.71	6.31	177.74	6.40	177.65	6.72	177.33	7.29	176.76
PZ-3	18.3	16	11.0-16.0	2	190.01	9.71	180.30	13.73	176.28	8.96	181.05	9.35	180.66	10.00	180.01	10.25	179.76	10.94	179.07
PZ-4	28.0	17	12.0-17.0	2	192.06	12.45	179.61	12.65	179.41	11.74	180.32	12.23	179.83	12.72	179.34	12.90	179.16	13.30	178.76
PZ-5	20.0	20	15.0-20.0	2	191.80	15.52	176.28	15.94	175.86	14.99	176.81	18.12	173.68	15.95	175.85	16.00	175.80	16.45	175.35
PZ-6	20.0	20	15.0-20.0	2	193.48	13.31	180.17	11.60	181.88	12.52	180.96	12.77	180.71	13.60	179.88	13.81	179.67	14.55	178.93
PZ-7	17.3	17.3	11.0-16.0	2	190.82	8.99	181.83	8.70	182.12	8.10	182.72	8.66	182.16	9.42	181.40	9.64	181.18	10.44	180.38
Stream Gauges																			
SG-N1	--	--	--	--	177.73	2.30	175.43	1.45	176.28	1.20	176.53	1.78	175.95	Dry	--	--	--	Dry	--
SG-N2	--	--	--	--	173.28	--	--	0.51	172.77	1.35	171.93	1.63	171.65	1.65	171.63	--	--	1.63	171.65
SG-N3	--	--	--	--	173.31	--	--	1.51	171.80	1.70	171.61	1.76	171.55	1.95	171.36	--	--	1.93	171.35
SG-N4	--	--	--	--	173.95	--	--	--	--	--	--	--	--	3.06	170.89	--	--	3.15	170.80
SG-E1	--	--	--	--	163.61	0.50	163.11	0.80	162.81	0.84	162.77	1.07	162.54	1.16	162.45	--	--	1.10	162.51
SG-E2	--	--	--	--	168.38	--	--	--	--	--	--	--	--	--	--	--	--	1.85	166.53
Weir										Height	Flow (cfs)	Height	Flow (cfs)	Height	Flow (cfs)	Height	Flow (cfs)	Height	Flow (cfs)
W-1	--	--	--	--	--	--	--	--	--	0.283	0.107	0.211	0.051	0.210	0.051	--	--	0.141	0.019

Monitoring Point ID	Construction Details				Water Level Monitoring														
	Borehole Depth	Piezometer Depth	Screen Depth	Piezometer Diameter	Measuring Point Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation	Depth to Water	Ground Water Elevation
	(ft bgs)	(ft bgs)	(ft bgs)	(inches)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)	(ft bmp)	(ft amsl)
						13-Oct-05		6-Dec-05		23-Feb-06		7-Apr-06		15-May-06		28-Jan-07		22-Aug-07	
Piezometers																			
PZ-1	21.8	24	14.5-19.5	2	186.72	12.85	173.87	--	--	12.30	174.42	12.60	174.12	12.69	174.03	12.15	174.57	--	--
PZ-2	9.0	9	4.0-9.0	2	184.05	6.05	178.00	5.45	178.60	5.64	178.41	5.50	178.55	6.12	177.93	5.87	178.18	7.50	176.55
PZ-3	18.3	16	11.0-16.0	2	190.01	11.36	178.65	10.54	179.47	9.95	180.06	10.60	179.41	10.54	179.47	9.34	180.67	--	--
PZ-4	28.0	17	12.0-17.0	2	192.06	13.70	178.36	13.80	178.26	13.75	178.31	13.17	178.89	13.15	178.91	12.23	179.83	13.91	178.15
PZ-5	20.0	20	15.0-20.0	2	191.80	16.28	175.52	15.85	175.95	11.15	180.65	16.15	175.65	16.20	175.60	15.64	176.16	16.78	175.02
PZ-6	20.0	20	15.0-20.0	2	193.48	15.00	178.48	14.10	179.38	13.51	179.97	14.05	179.43	14.08	179.40	13.87	179.61	15.02	178.46
PZ-7	17.3	17.3	11.0-16.0	2	190.82	10.62	180.20	10.00	180.82	12.20	178.62	10.00	180.82	10.01	180.81	17.08	173.74	10.68	180.14
Stream Gauges																			
SG-N1	--	--	--	--	177.73	2.05	175.68	1.81	175.92	1.84	175.89	1.50	176.23	1.90	175.83	1.84	175.89	Dry	--
SG-N2	--	--	--	--	173.28	1.96	171.32	1.98	175.75	1.80	171.48	1.65	171.63	1.66	171.62	--	--	--	--
SG-N3	--	--	--	--	173.31	1.95	171.36	1.73	176.00	1.98	171.33	1.90	171.41	1.98	171.33	2.10	171.21	--	--
SG-N4					173.95	3.20	170.75	3.17	170.78	2.96	170.99	3.10	170.85	2.96	170.99	2.75	171.20	2.87	171.08
SG-E1	--	--	--	--	163.61	1.10	162.51	1.00	162.61	1.02	162.59	1.04	162.57	1.02	162.59	1.12	162.49	--	--
SG-E2					168.38	1.78	166.60	1.52	166.86	1.67	166.71	1.74	166.64	1.77	166.61	1.70	166.68	--	--
Weir						Height	Flow (cfs)	Height	Flow (cfs)	Height	Flow (cfs)	Height	Flow (cfs)	Height	Flow (cfs)	Height	Flow (cfs)	Height	Flow (cfs)
W-1	--	--	--	--	--	0.150	0.022	0.175	0.032	0.197	0.043	0.130	0.015	0.156	0.024	0.250	0.078	--	--

Notes:

-- Not Measured or Not Applicable.
ft amsl - Feet Above Mean Sea Level.
ft bgs - Feet Below Ground Surface.
ft bmp - Feet Below Measuring Point.
cfs - Flow rate through weir in cubic feet per second.
Weir Equation - $Q=2.5*H^{(5/2)}$ Q in cubic feet per second

Table 2. Field Estimates of Hydraulic Conductivity
Piney Branch Bog
Charles County, Maryland

Well ID	**USCS Soil Classification (a)**	**Field Measured (b) Hydraulic Conductivity**	
		cm/sec	**ft/day**
PZ-1	ML-CL * (silt and clay)	1.7 E-3	4.9
PZ-2	GW-SC (well graded gravel and some clay)	5.3 E-3	15.1
PZ-3	GM (silty gravel)	7.7 E-4	2.2
PZ-5	GW-SC (sand and gravel with little clay)	2.6 E-3	7.3
Statistics			
Maximum		5.3 E-3	15.1
Minimum		7.7 E-4	2.2
Arithmetic Mean		2.6 E-3	7.3
Standard Deviation		2.0 E-3	5.5

Notes:
(a) U.S. Army Engineers Waterways Experiment Station (1960) and Howard (1977).
(b) Method developed by Wilson, Cho, Beck and Vardy, 1997.
cm/sec - centimeters per second.
ft/day - feet per day.
* Conductivity at PZ-1 is attributable to a silty gravel pocket intersecting the filter pack.

Table 3A. Analytes Detected in Ground Water and Surface Water Samples, July 2005
Piney Branch Bog, Charles County, Maryland

		Laboratory Sample Number:	GW-1	GW-2	GW-3	GW-4	GW-5	DUP	GW-6	GW-7	SW-1	SW-2	SW-3
		ERM ID number:	**PZ-1**	**PZ-2**	**PZ-3**	**PZ-4**	**PZ-5**	**PZ-5[DUP]**	**PZ-6**	**PZ-7**	**SG-N1**	**SG-N4**	**SG-E1**
		BTAG	**Ground Water**								**Surface Water**		
Parameter	**Units**	**Benchmarks**	**7/27/05**	**7/27/05**	**7/27/05**	**7/27/05**	**7/27/05**	**7/27/05**	**7/27/05**	**7/27/05**	**7/27/05**	**7/27/05**	**7/27/05**
TCL VOCs													
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCL SVOCs													
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCBs													
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCL Pesticides													
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCL Herbicides													
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Inorganic Trace Elements (Dissolved)													
Barium	mg/l	0.004	**0.12**	**0.042**	**0.029**	**0.041**	**0.037**	**0.028**	**0.037**	**0.037**	**0.10**	**0.10**	**0.011**
Cobalt	mg/l	0.023	0.006	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Manganese	mg/l	0.12	0.11	0.044	**0.20**	0.051	**0.17**	0.035	**0.17**	0.041	0.089	0.091	0.009
Silver	mg/l	0.0003	**0.005**	<0.005	**0.010**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc	mg/l	0.036	0.012	0.027	0.019	0.021	0.017	0.022	0.014	0.013	0.020	0.018	<0.005
Cations													
Aluminum	mg/l	0.087	**0.25**	**0.8084**	0.061	**0.41**	0.063	0.064	0.082	0.076	**0.22**	**0.18**	0.017
Calcium	mg/l	0.16	**3.1**	**1.2**	**2.2**	**2.9**	**4.0**	**0.8**	**4.1**	**0.8**	**2.5**	**2.8**	**2.4**
Iron	mg/l	0.3	<0.05	<0.05	<0.05	**0.37**	<0.05	<0.05	<0.05	<0.05	0.09	0.10	<0.05
Magnesium	mg/l	82	1.7	1.1	0.8	1.1	1.1	0.9	1.2	0.8	1.2	1.5	1.4
Potassium	mg/l	53	1.1	0.5	0.6	0.9	0.6	0.4	0.5	0.3	0.8	1.0	0.7
Sodium	mg/l	680	41	12	13	46	9.8	10	10.4	9.7	32	33	31
Anions													
Chloride	mg/l	230	57.0	3.0	9.0	26.0	2.6	3.0	3.2	3.0	42	43	43
Fluoride	mg/l	0.603	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Nitrate	mg/l	--	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrite	mg/l	0.02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sulfate	mg/l	--	6.5	4.0	6.7	12.0	9.0	4.0	11.0	4.4	5	5	5
Alkalinity													
Bicarbonate	mg/l	--	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Carbonate	mg/l	--	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
pH - 4.5	mg/l	--	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
pH - 8.3	mg/l	--	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Field Parameters													
pH	--	6.5-9	--	--	**5.10**	**4.5**	**4.78**	--	--	--	--	--	--
Conductance	mS/cm	--	--	--	0.054	0.114	0.037	--	--	--	--	--	--
Dissolved Oxygen	mg/l	--	--	--	2.05	3.19	3.78	--	--	--	--	--	--
Redox Potential	mV	--	--	--	1.7	18.1	69.0	--	--	--	--	--	--

Footnotes:

bold indicates levels above the BTAG Benchmarks
mg/L - milligrams per liter.
mS/cm - millisemens per centimeter
mV - millivolts
ND - None Detected
-- Not Available
BTAG Benchmarks - United States Enivonrmental Protection Agency (USEPA) Region III Biological Technical Assistance Group (BTAG) Freshwater Screening Benchmarks. Presented for discussion purposes only.
Inorganic trace elements not detected: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, thallium, and van
TCL VOCs - Target Compound List Volatile Organic Compounds by EPA Method 8260.
TCL SVOCs - Target Compound List Semivolatile Organic Compounds by EPA Method 8270.
TCL Pesticides - Target Compound List Pesticide Compounds by EPA Method 8081.
TCL Herbicides - Target Compound List Herbicide Compounds by EPA Method 8151.
PCBs - Polychlorinated Binphenyl Compounds by EPA Method 8082.
PPL Metals - Priority Pollutant List Metals by EPA Method Series 200.
Anions by EPA Method 300.
Field parameters were measured using electronic meters.

Table 3B. Analytes Detected in Ground Water and Surface Water Samples, May 2006
Piney Branch Bog, Charles County, Maryland

		Laboratory Sample Number:	GW-1	GW-2	DUP	GW-3	GW-4	GW-5	GW-6	GW-7	SW-1	SW-2	SW-3
		ERM ID number:	**PZ-1**	**PZ-2**	**PZ-2[DUP]**	**PZ-3**	**PZ-4**	**PZ-5**	**PZ-6**	**PZ-7**	**SG-N1**	**W-1**	**SG-E2**
		MDE GW	**Ground Water**								**Surface Water**		
Parameter	**Units**	**Standard**	**5/15/06**	**5/15/06**	**5/15/06**	**5/15/06**	**5/15/06**	**5/15/06**	**5/15/06**	**5/15/06**	**5/15/06**	**5/15/06**	**5/15/06**
TCL VOCs													
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCL SVOCs													
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCBs													
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCL Pesticides													
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCL Herbicides													
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Inorganic Trace Elements (Dissolved)													
Barium	mg/l	0.004	**0.120**	**0.021**	**0.022**	**0.036**	**0.20**	**0.049**	**0.19**	**0.047**	**0.40**	**0.13**	**0.11**
Cobalt	mg/l	0.023	0.005	<0.005	<0.005	0.005	0.010	<0.005	0.009	<0.005	**0.044**	<0.005	<0.005
Copper	mg/l	1.3	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	0.024	<0.005	<0.005
Lead	mg/l	0.015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	**0.073**	<0.005	<0.005
Manganese	mg/l	0.12	0.093	0.034	0.039	**0.27**	**0.26**	**0.19**	**0.16**	0.039	**0.58**	0.098	0.094
Nickel	mg/l	0.073	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	0.006	<0.005	0.022	<0.005	<0.005
Vanadium	mg/l	0.05	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	**0.052**	<0.002	<0.002
Zinc	mg/l	0.036	**0.15**	**0.22**	**0.048**	**0.21**	**0.082**	**0.15**	**0.11**	**0.050**	**0.21**	**0.073**	**0.069**
Cations													
Aluminum	mg/l	0.087	**0.28**	**0.094**	**0.11**	0.052	**1.6**	**0.13**	**1.1**	0.073	**15**	**0.77**	**0.36**
Calcium	mg/l	0.16	**1.8**	**2.4**	**2.3**	**2.1**	**3.0**	**5.4**	**2.7**	**0.9**	**7.5**	**2.1**	**2.0**
Iron	mg/l	0.3	0.016	0.050	0.065	0.041	0.011	0.014	0.048	0.064	**17**	**1.60**	**0.40**
Magnesium	mg/l	82	1.3	1.0	0.99	0.78	2.6	1.7	2.3	0.99	2.4	1.6	1.5
Potassium	mg/l	53	0.86	0.96	1.1	0.50	1.4	0.58	0.98	0.40	1.4	0.67	0.61
Sodium	mg/l	680	21	43	44	4.1	35	1.3	42	6.7	34	19	17
Anions													
Chloride	mg/l	230	37	78	76	8.8	73	4.7	95	13	63	40	33
Fluoride	mg/l	0.603	0.1	0.1	0.1	0.1	0.2	<0.1	0.2	0.1	0.1	0.1	0.1
Nitrate	mg/l	--	<0.1	<0.1	<0.1	<0.1	1.1	0.9	<0.1	<0.1	0.2	<0.1	<0.1
Nitrite	mg/l	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate	mg/l	--	11	11	11	10	13	16	14	9.3	11	11	11
Alkalinity													
Bicarbonate	mg/l	--	<10	<10	10	<10	90	<10	<10	<10	<10	<10	<10
Carbonate	mg/l	--	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
pH - 4.5	mg/l	--	<10	<10	10	<10	90	<10	<10	<10	<10	<10	<10
pH - 8.3	mg/l	--	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Field Parameters													
pH	--	6.5-9	**4.30**	**5.09**	--	**5.07**	**4.21**	**4.52**	**4.24**	**4.19**	**5.45**	**4.76**	**4.76**
Conductance	mS/cm	--	0.153	0.278	--	0.058	0.287	0.056	0.328	0.055	0.198	0.156	0.135
Dissolved Oxygen	mg/l	--	9.58	6.56	--	6.26	9.42	3.37	4.18	3.96	3.80	7.49	7.04
Redox Potential	mV	--	373	266.1	--	300.8	319.1	230.8	316.6	315.6	276.1	271.2	352.8

Footnotes:

bold indicates levels above the BTAG Benchmarks
mg/L - milligrams per liter.
mS/cm - millisemens per centimeter
mV - millivolts
ND - None Detected
-- Not Available
BTAG Benchmarks - United States Enivonrmental Protection Agency (USEPA) Region III Biological Technical Assistance Group (BTAG) Freshwater Screening Benchmarks. Presented for discussion purposes only.
Inorganic trace elements not detected: antimony, arsenic, beryllium, cadmium, chromium, mercury, selenium, silver, and thallium.
TCL VOCs - Target Compound List Volatile Organic Compounds by EPA Method 8260.
TCL SVOCs - Target Compound List Semivolatile Organic Compounds by EPA Method 8270.
TCL Pesticides - Target Compound List Pesticide Compounds by EPA Method 8081.
TCL Herbicides - Target Compound List Herbicide Compounds by EPA Method 8151.
PCBs - Polychlorinated Binphenyl Compounds by EPA Method 8082.
PPL Metals - Priority Pollutant List Metals by EPA Method Series 200.
Anions by EPA Method 300.
Field parameters were measured using electronic meters.

Table 3C. Analytes Detected in Ground Water and Surface Water Samples, August 2007
Piney Branch Bog, Charles County, Maryland

		Laboratory Sample Number:	P2-2	P2-4	P2-5	P2-6	P2-7	P2-7[DUP]	SF-N4
		ERM ID number:	**PZ-2**	**PZ-4**	**PZ-5**	**PZ-6**	**PZ-7**	**PZ-7[DUP]**	**SG-N4**
		MDE GW	**Ground Water**						**Surface Water**
Parameter	**Units**	**Standard**	**8/22/07**	**8/23/07**	**8/23/07**	**8/22/07**	**8/22/07**	**8/22/07**	**8/23/07**
VOCs (BTEX, MTBE, and Napthalene only)									
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND
SVOCs (PAHs only)									
None Detected	mg/l	--	ND	ND	ND	ND	ND	ND	ND
Inorganic Trace Elements (Dissolved)									
Barium	mg/l	0.004	**0.014**	**0.061**	**0.034**	**0.066**	**0.045**	**0.044**	**0.101**
Manganese	mg/l	0.12	0.011	0.061	0.076	0.066	0.029	0.029	0.071
Zinc	mg/l	0.036	0.010	0.010	0.008	0.023	0.009	0.008	0.014
Cations									
Aluminum	mg/l	0.087	0.067	**0.396**	0.086	0.067	0.057	0.052	**1.39**
Calcium	mg/l	0.16	**1.78**	**1.35**	**7.13**	**4.40**	**0.525**	**0.478**	**1.95**
Iron	mg/l	0.3	0.026	<0.020	<0.020	0.021	<0.020	<0.020	**1.84**
Magnesium	mg/l	82	0.571	0.734	1.46	1.96	0.752	0.749	1.17
Potassium	mg/l	53	1.34	1.28	1.41	1.00	0.696	0.552	0.807
Sodium	mg/l	680	40.1	18.5	1.46	15.6	16.1	15.6	22.4
Anions									
Chloride	mg/l	230	54	23	5.4	22	20	20	34
Fluoride	mg/l	0.603	0.27	0.33	0.33	0.37	0.30	0.12	0.16
Nitrate	mg/l	--	0.5	0.2	0.5	0.2	0.3	0.4	0.1
Nitrite	mg/l	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate	mg/l	--	13	17	22	14	14	13	12
Alkalinity									
Bicarbonate	mg/l	--	10	<10	<10	18	<10	<10	<10
Carbonate	mg/l	--	<10	<10	<10	<10	<10	<10	<10
pH - 4.5	mg/l	--	10	<10	<10	18	<10	<10	<10
pH - 8.3	mg/l	--	<10	<10	<10	<10	<10	<10	<10
Field Parameters									
pH	--	6.5-9	**5.02**	**4.29**	**4.65**	**5.33**	**4.67**	--	**4.81**
Conductance	mS/cm	--	0.228	0.129	0.063	0.135	0.136	--	0.150
Dissolved Oxygen	mg/l	--	5.13	4.75	2.17	1.81	6.83	--	7.79
Redox Potential	mV	--	247	259	234	195	267	--	242

Footnotes:

bold indicates levels above the BTAG Benchmarks
mg/L - milligrams per liter.
mS/cm - millisemens per centimeter
mV - millivolts
ND - None Detected
-- Not Available
BTAG Benchmarks - United States Enivonrmental Protection Agency (USEPA) Region III Biological Technical Assistance Group (BTAG) Freshwater Screening Benchmarks. Presented for discussion purposes only.
Inorganic trace elements not detected: antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, silver, thallium, and vanadium.
TCL VOCs - Target Compound List Volatile Organic Compounds by EPA Method 8260.
TCL SVOCs - Target Compound List Semivolatile Organic Compounds by EPA Method 8270.
TCL Pesticides - Target Compound List Pesticide Compounds by EPA Method 8081.
TCL Herbicides - Target Compound List Herbicide Compounds by EPA Method 8151.
PCBs - Polychlorinated Binphenyl Compounds by EPA Method 8082.
PPL Metals - Priority Pollutant List Metals by EPA Method Series 200.
Anions by EPA Method 300.
Field parameters were measured using electronic meters.

Table 4. Ground Water Flow Model Parameters
Piney Branch Bog
Charles County, Maryland

Input Parameter	**Calvert Clay**	**Upland Deposit Sand & Gravel (Stream Valley Areas)**	**Upland Deposit Sand & Gravel (Plateau Area)**	**Units**	**Source/Note**
Base elevation	30	169	178	feet, amsl	Based on simplified observed data
Effective porosity	0.3	0.3	0.3	dimensionless	Fetter, 1994
Hydraulic conductivity	0.38	13.5	270	feet per day	Model calibration, field-calculated values.
Surface stream elevation	Variable			feet, amsl	USGS quads
Infiltration rate	8.6			inches per year	Model calibration
Stream flow rate, W-1	0.047			cubic feet per second	Average of observed

Table 5. Ground Water Flow Model Calibration Results
Piney Branch Bog
Charles County, Maryland

Well	Observed Water Level (ft msl)[1]	Modeled Water Level (ft msl)	Residual (ft)	Relative Residual	Criteria
Average Flow Conditions and Water Levels					
PZ-1	174.21	174.09	-0.12		
PZ-2	177.85	177.98	0.13		
PZ-3	179.99	179.68	-0.31		
PZ-4	179.08	178.63	-0.45		
PZ-5	176.16	176.63	0.47		
PZ-6	179.78	179.76	-0.02		
PZ-7	181.07	181.43	0.36		
Maximum	181.07				
Minimum	174.21				
Difference	6.86				
Average			0.01	***-0.1%***	**<2%**
STD			0.31	***4.5%***	**<10%**

[1]Value is the average of all available water levels for each corresponding PZ location.

Figures

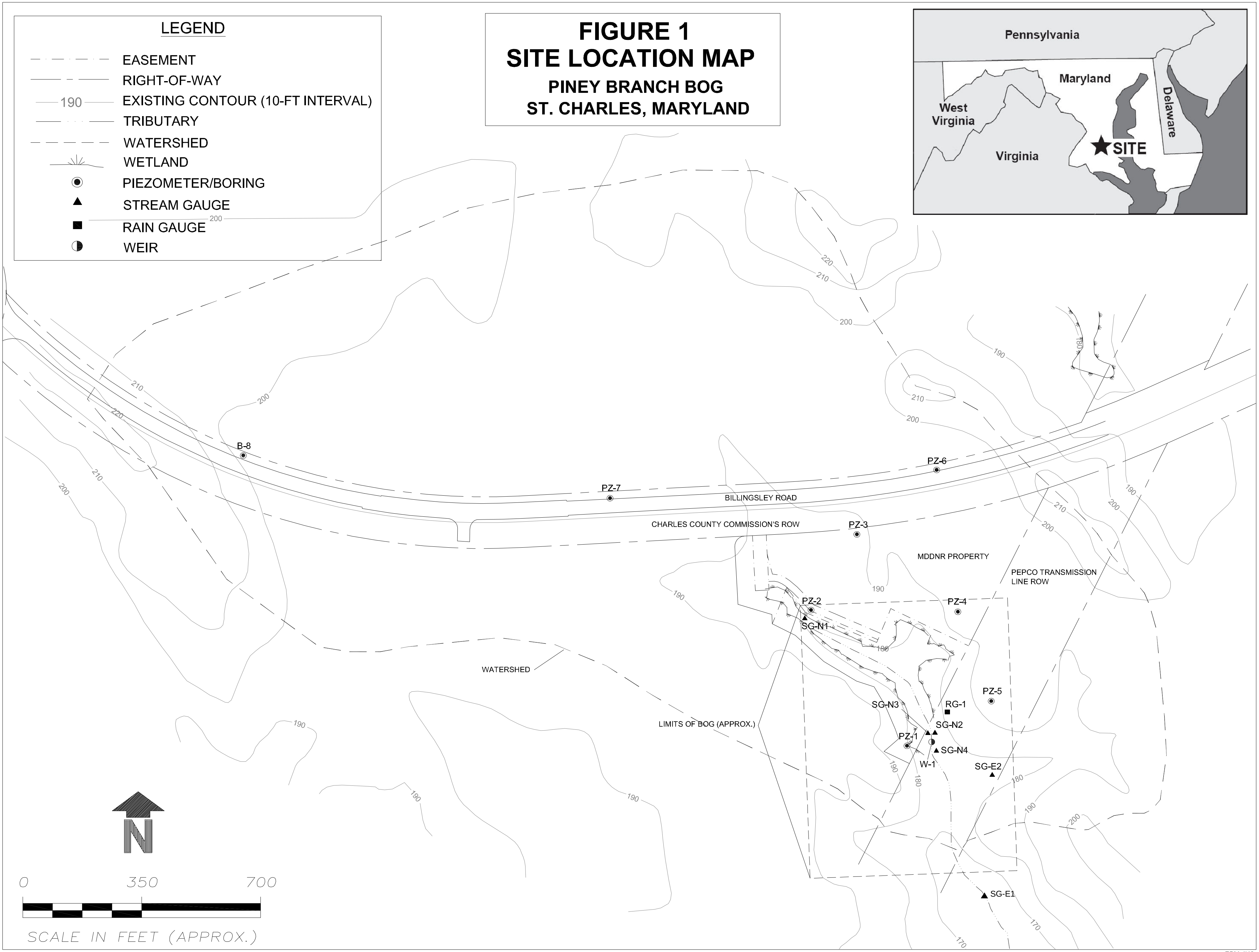
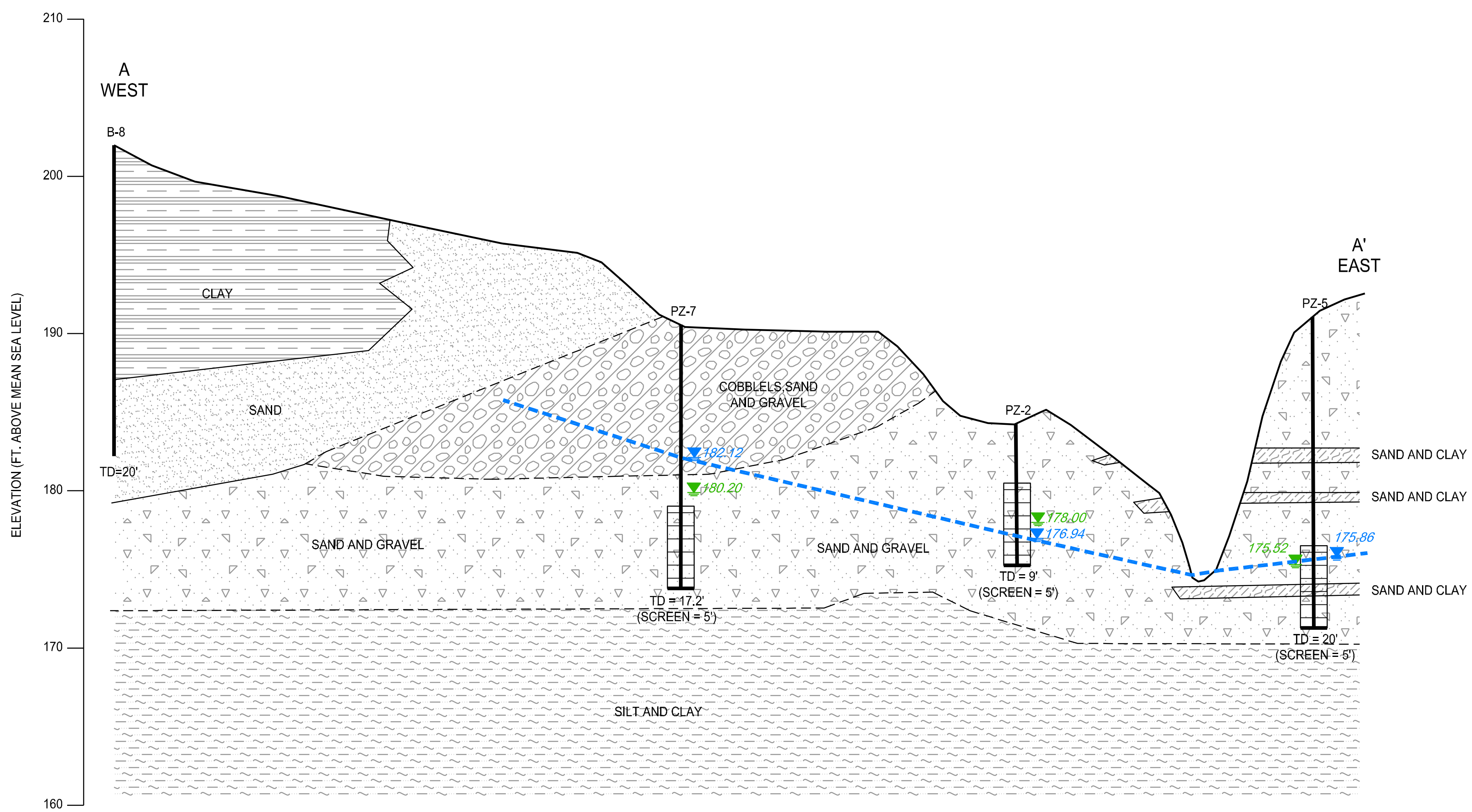
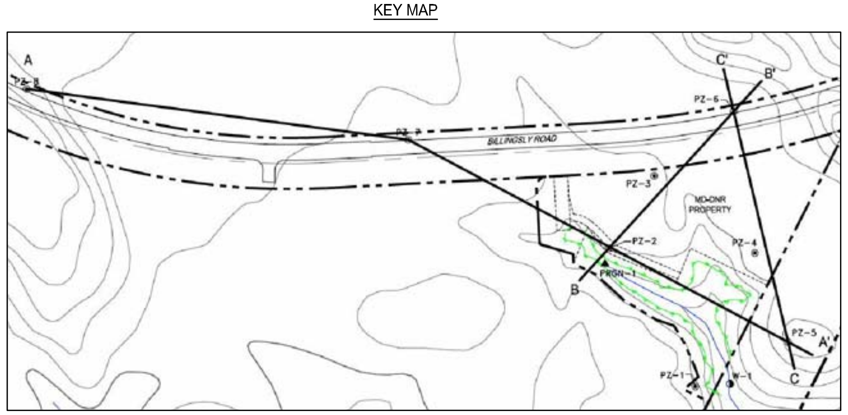


FIGURE 1
SITE LOCATION MAP
PINEY BRANCH BOG
ST. CHARLES, MARYLAND
LEGEND
EASEMENT
RIGHT-OF-WAY
190 EXISTING CONTOUR (10-FT INTERVAL)
TRIBUTARY
WATERSHED
WETLAND
PIEZOMETER/BORING
STREAM GAUGE
RAIN GAUGE
WEIR
Pennsylvania
Maryland
West Virginia
Delaware
Virginia
SITE
BILLINGSLEY ROAD
CHARLES COUNTY COMMISSION'S ROW
MDDNR PROPERTY
PEPCO TRANSMISSION LINE ROW
WATERSHED
LIMITS OF BOG (APPROX.)
B-8
PZ-7
PZ-6
PZ-3
PZ-2
PZ-4
PZ-5
PZ-1
SG-N1
SG-N2
SG-N3
SG-N4
SG-E1
SG-E2
RG-1
W-1
0 350 700
SCALE IN FEET (APPROX.)
ERM, INC.

FIGURE 2A
CROSS-SECTION A-A'
PINEY BRANCH BOG
CHARLES COUNTY, MARYLAND



KEY MAP



LEGEND

PZ	PIEZOMETER
TD	TOTAL DEPTH
162.82	22 APRIL 2005 WATER LEVEL
- - -	22 APRIL 2005 WATER LEVEL CONTOUR
162.51	13 OCTOBER 2005 WATER LEVEL
	WELL
	SCREEN INTERVAL
— — — —	INFERRED BOUNDARY

300 150 0 300

HORIZONTAL SCALE IN FEET
VERTICAL EXAGGERATION = 30X

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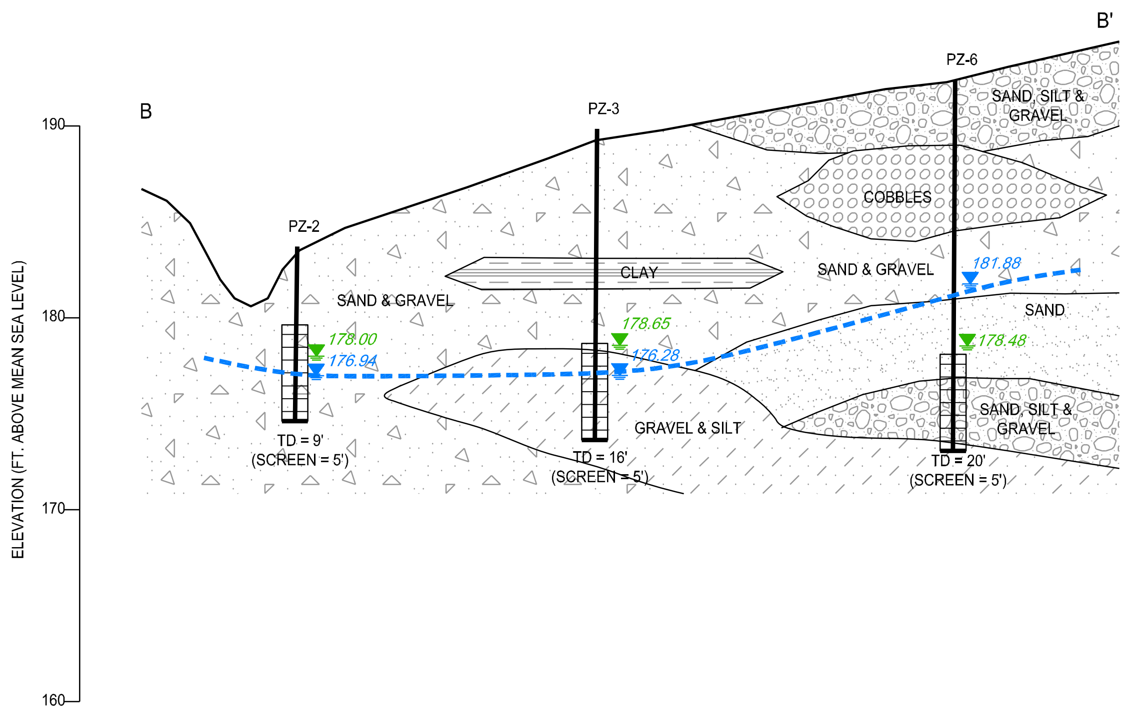
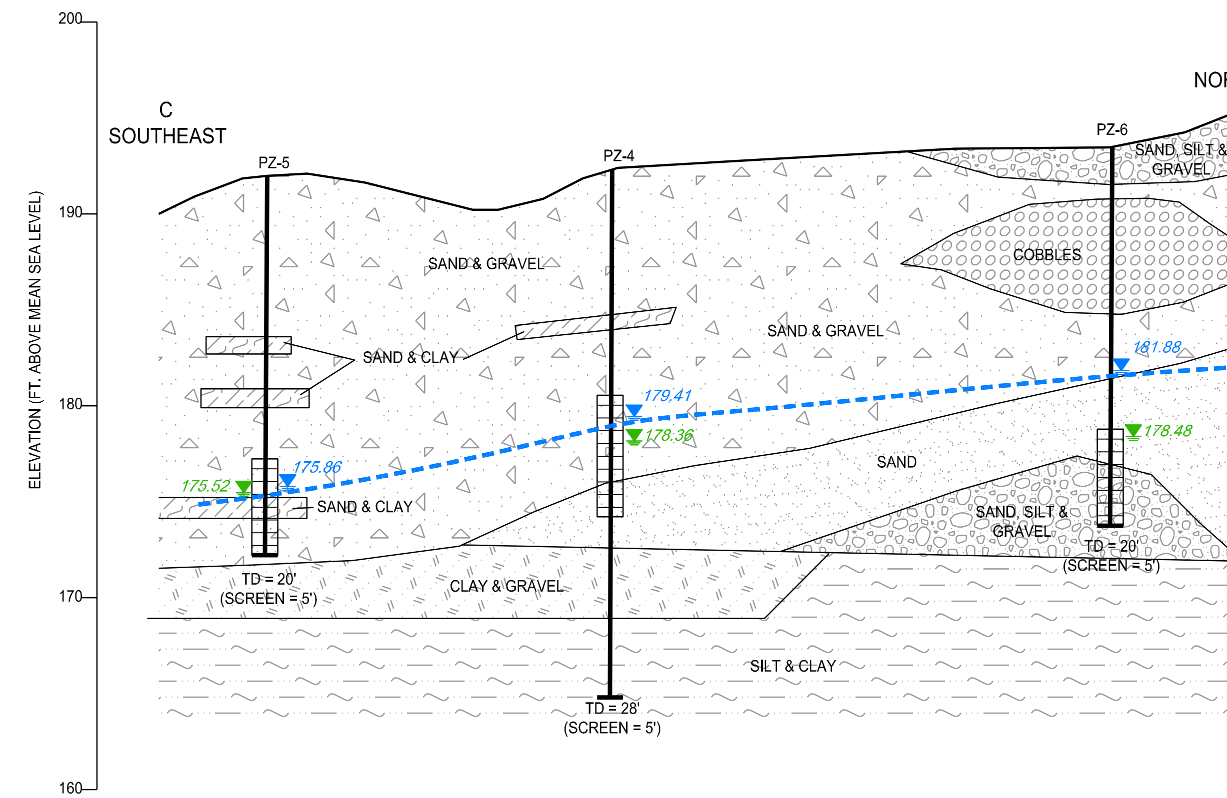
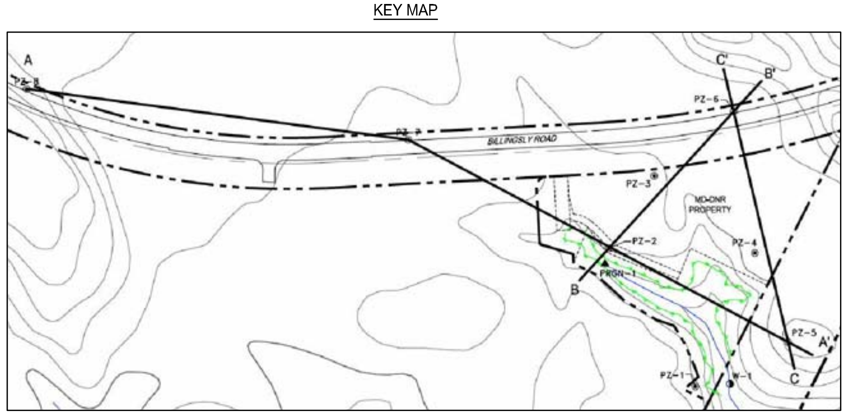
FIGURE 2B
CROSS-SECTIONS B-B' AND C-C'
PINEY BRANCH BOG
CHARLES COUNTY, MARYLAND





KEY MAP



LEGEND

PZ PIEZOMETER

TD TOTAL DEPTH

162.82 22 APRIL 2005 WATER LEVEL

22 APRIL 2005 WATER LEVEL CONTOUR

162.82 13 OCTOBER 2005 WATER LEVEL

WELL

SCREEN INTERVAL

INFERRED BOUNDARY

150 75 0 150

HORIZONTAL SCALE IN FEET

VERTICAL EXAGGERATION = 15X

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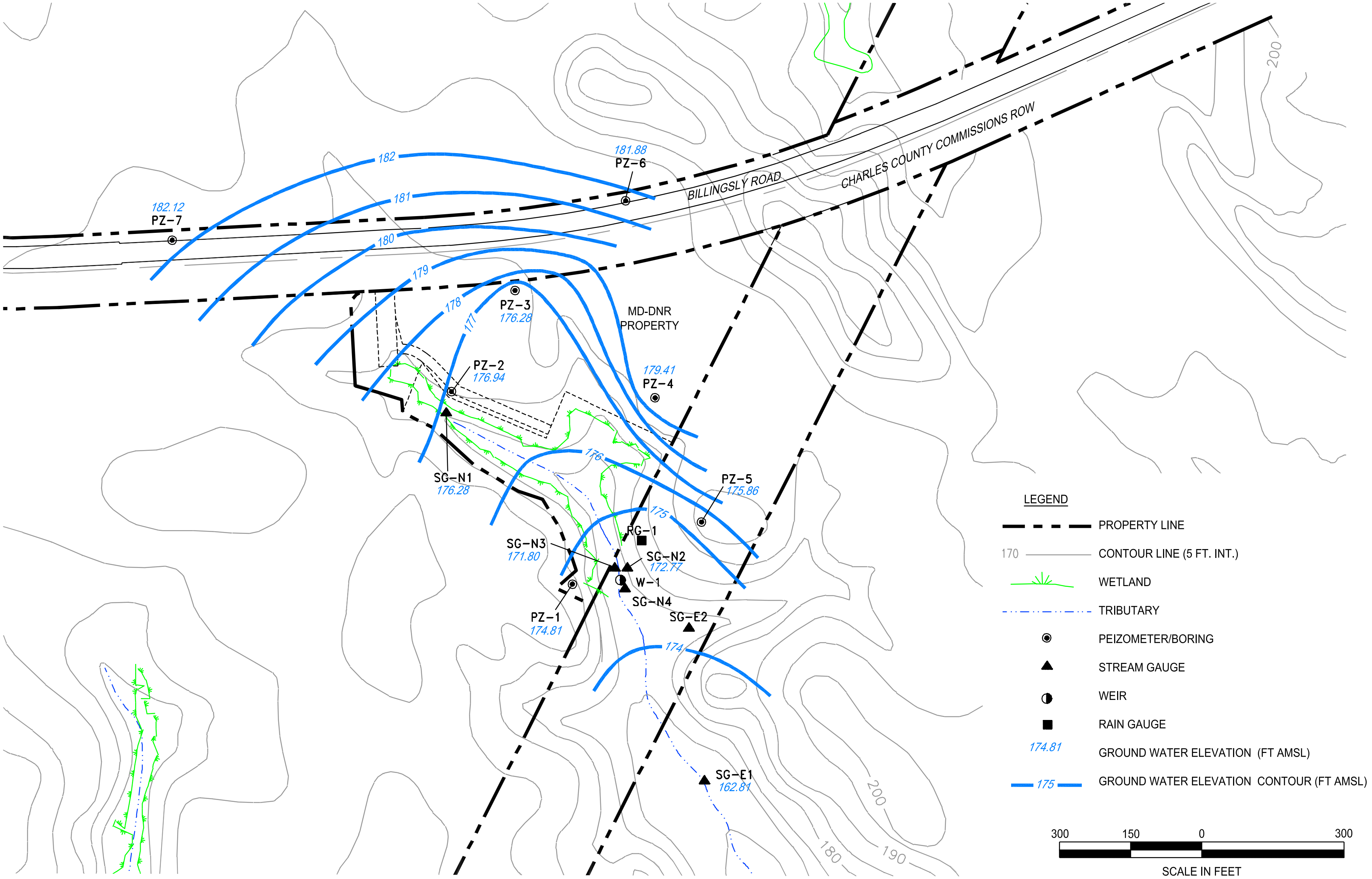
FIGURE 3
GROUND WATER CONTOUR MAP
22 APRIL 2005
PINEY BRANCH BOG
CHARLES COUNTY, MARYLAND



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MLB/11-10-08

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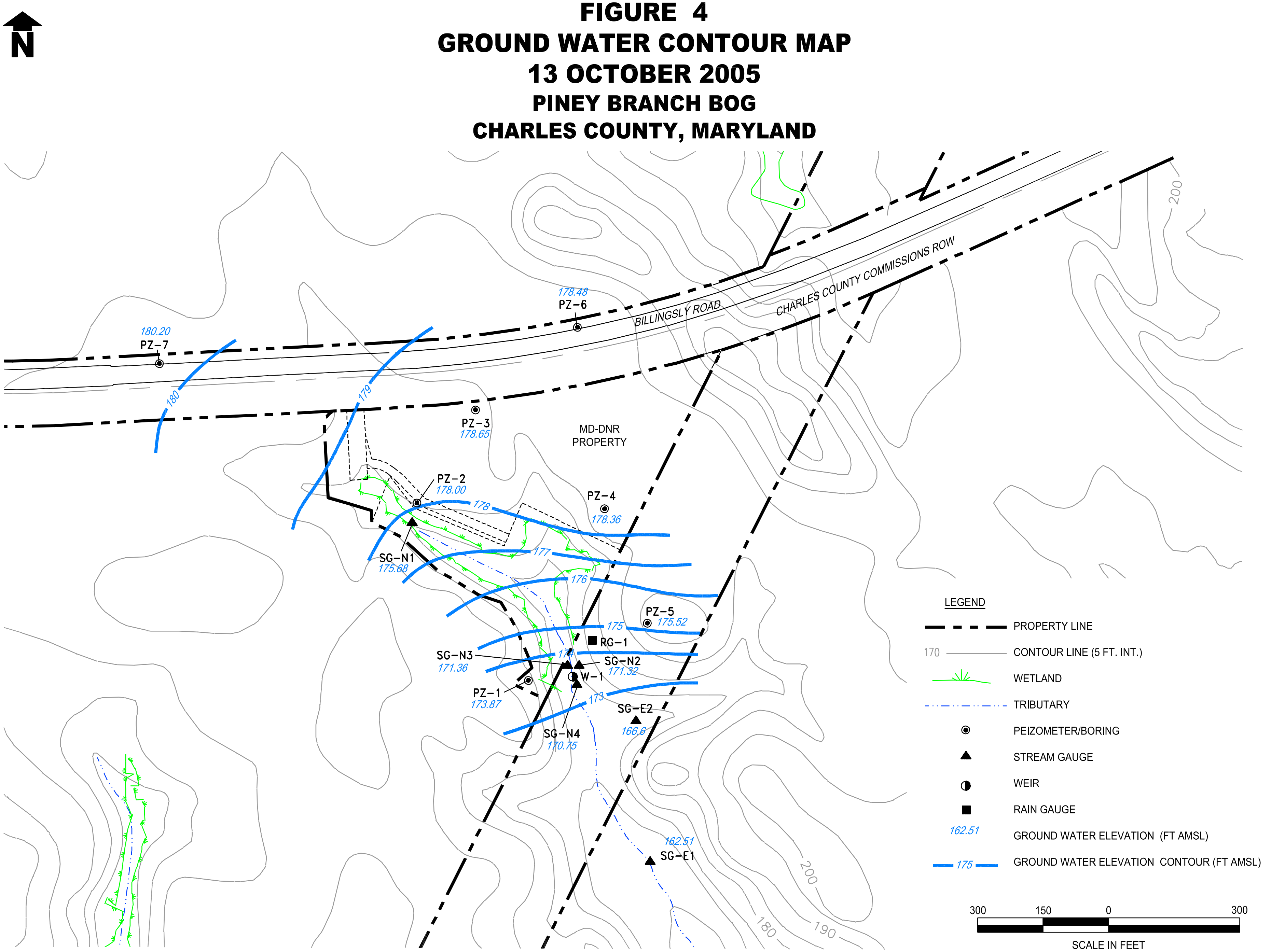
FIGURE 4
GROUND WATER CONTOUR MAP
13 OCTOBER 2005
PINEY BRANCH BOG
CHARLES COUNTY, MARYLAND



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MLB/11-10-08

ERM, INC.

FIGURE 5
HYDROGRAPH, ANDREWS AIR FORCE BASE DATA
23 JUNE 2005 - 13 OCTOBER 2005
PINEY BRANCH BOG
CHARLES COUNTY, MARYLAND

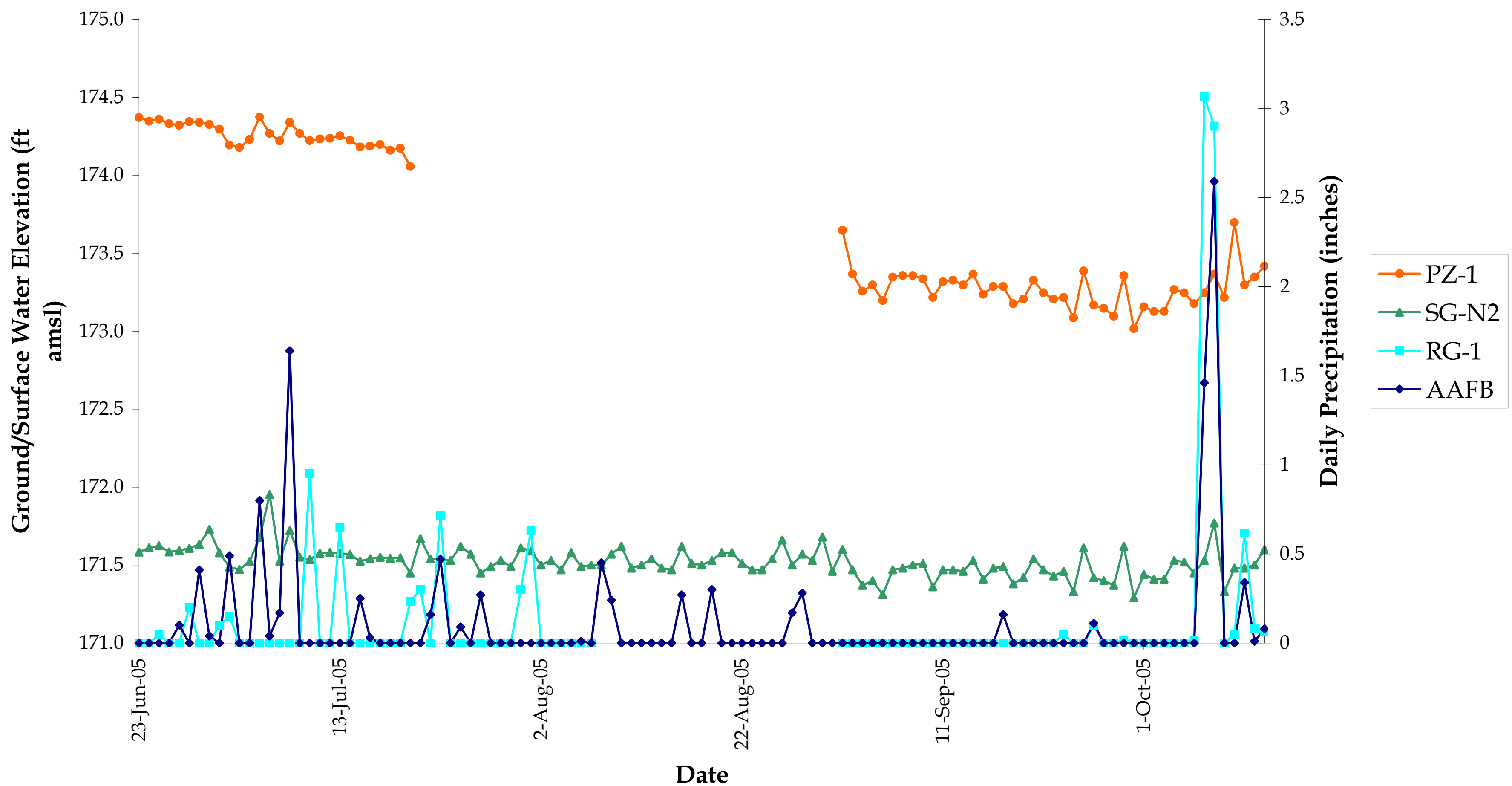


FIGURE 6
HYDROGRAPH, PRECIPITATION EVENT
1 - 13 OCTOBER 2005
PINEY BRANCH BOG
CHARLES COUNTY, MARYLAND

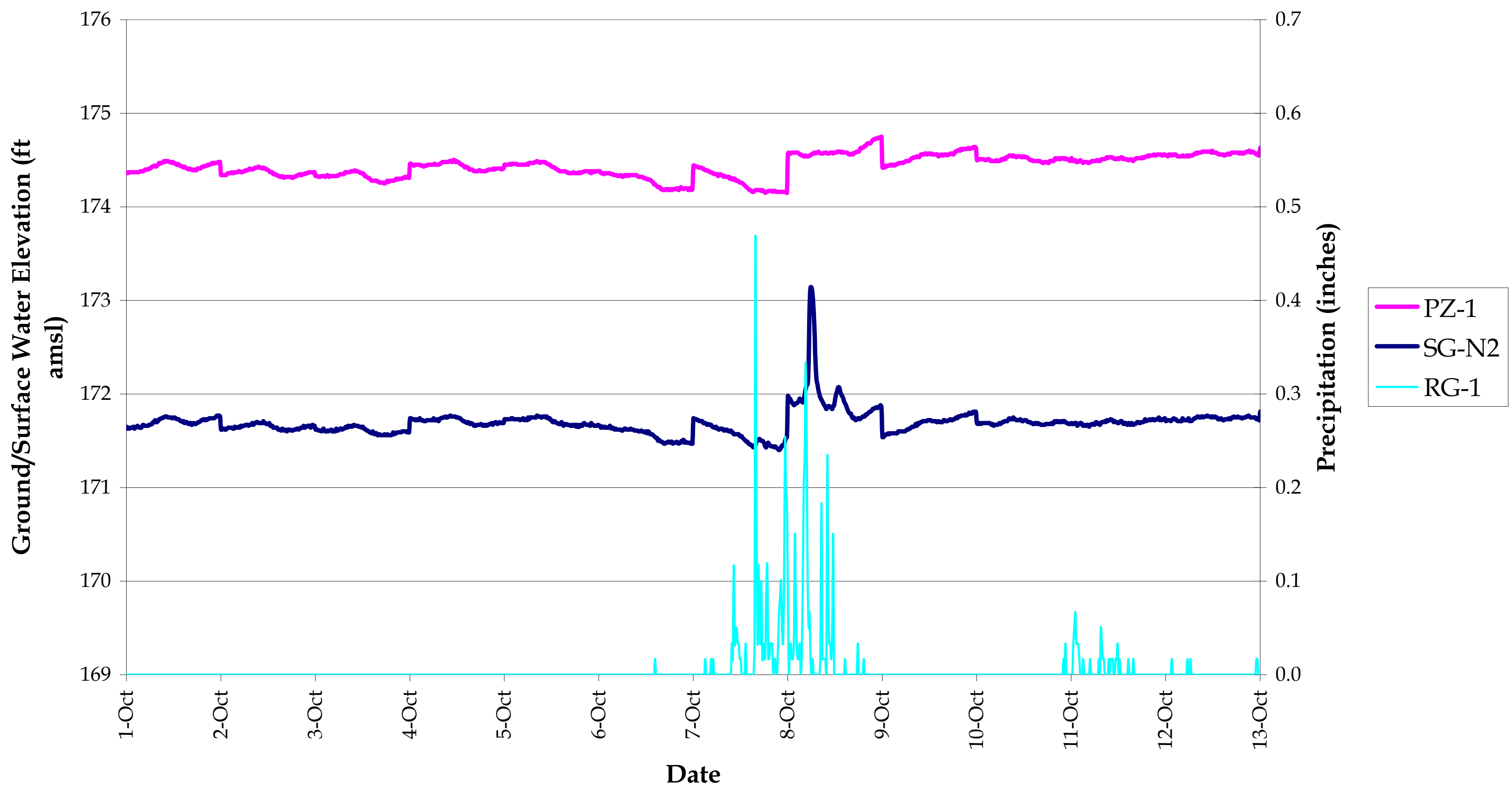


Figure 7. Ground Water Flow Model Area

Legend

⊕ Well/piezometer

Stream

Scale: 1" = 1,000'

N

Aerial Photograph Date: circa 2001

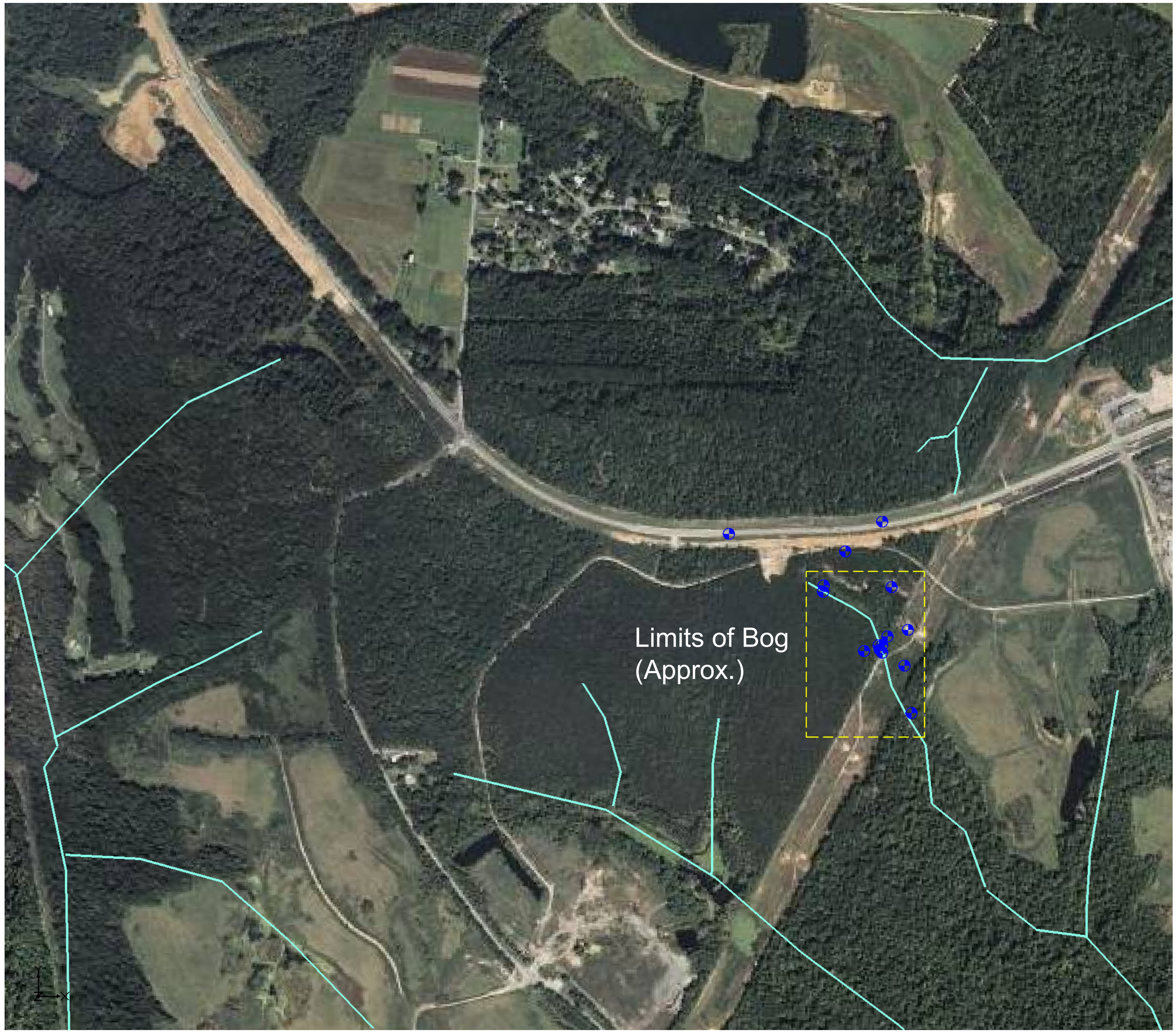
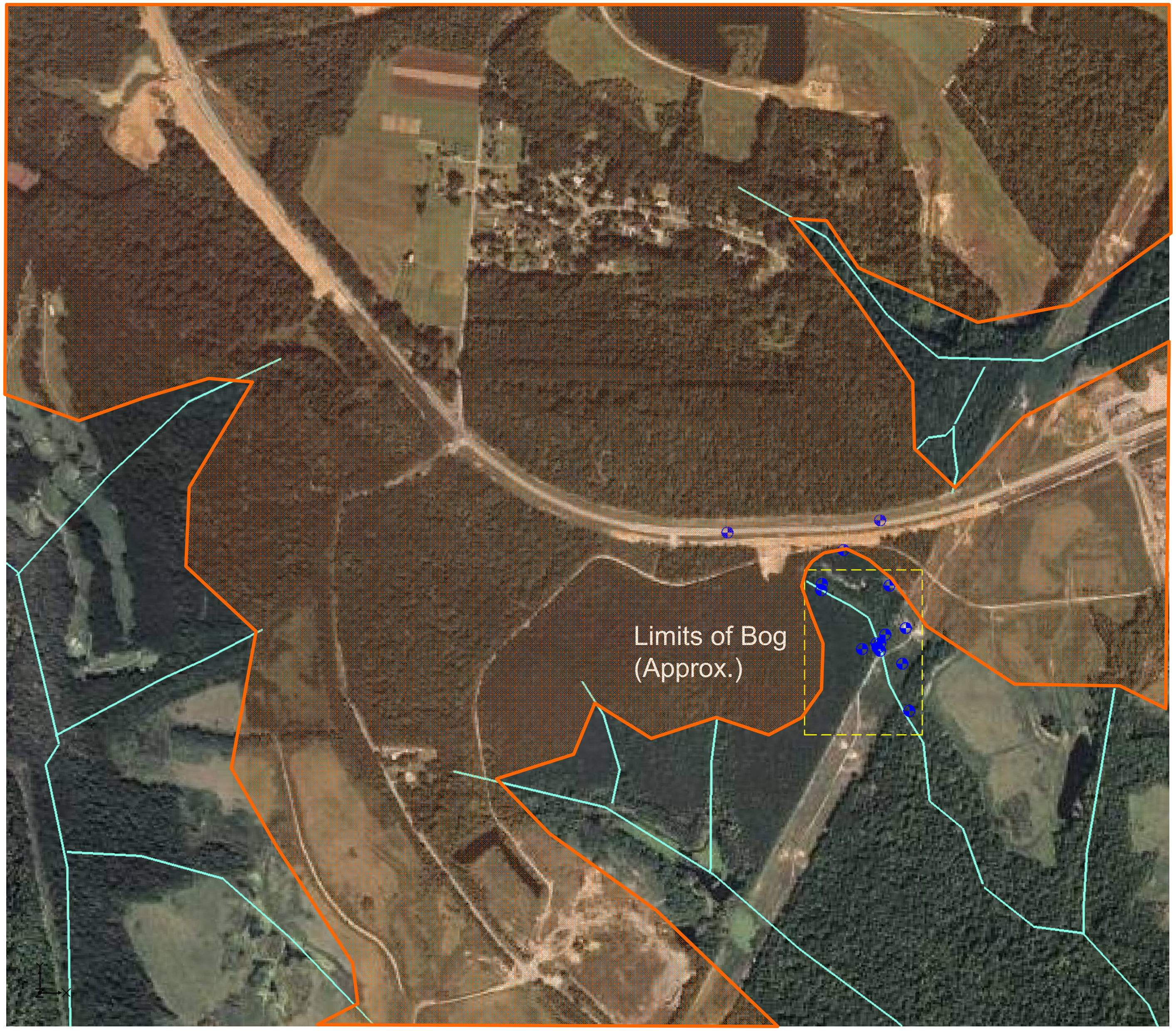


Figure 8. Ground Water Flow Model - Upland Deposit Conductivity Distribution.



Legend

⊕ Well/Piezometer

Stream

Approximate area of High Permeability Sand & Gravel within the Upland Deposit

Scale: 1” = 1,000’

N

Aerial Photograph Date: circa 2001

Figure 9. Simulated Ground Water Flow Directions and Contours – Average Flow Conditions and Water Levels

Legend

- ⊕ Well/piezometer
- Stream
- Modeled ground water contour, ft amsl
- Modeled ground water flow line in Middle Sand Layer, 10-year travel time between arrows

Scale: 1" = 1,000'

N

Aerial Photograph Date: circa 2001