Section 4
Groundwater Model Data Review

Prior to conducting the groundwater modeling and transport analysis described in Sections 6 and 7, CDM performed a review of available data, including, but not limited to, modeling studies prepared for previous reports on the site, unsaturated zone modeling used to generate estimates of leachate production and infiltration, and post-construction water quality data. Regional hydrogeologic reports and models prepared by the United States Geological Survey (USGS) were also reviewed for this study.

The purpose of the data review was to gather information for the groundwater flow and transport modeling, and to critically review assumptions made by others concerning site conditions in the light of post-construction data gathered primarily in 2008 and 2009.

4.1 Modeling Review and Previous Reports

CDM performed a review of the principal reports that have been issued for the Battlefield Golf Course site. These include a study by GAI Consultants, Inc. (GAI) to determine how ammonia associated with the fly ash may impact groundwater in the site vicinity (GAI, 2003). GAI assumed that ammonia would be converted rapidly in the environment into nitrate, which is highly soluble and mobile in groundwater. Total ammonia concentrations in the fly ash were expected to be approximately 5–10 milligrams per kilogram (mg/kg), accounting for volatilization in handling during processing.

GAI used the model BUFFER1, a one-dimensional model to simulate uniform vertical flow, was used to simulate nitrate transport in the unsaturated zone and predict nitrate concentrations at the water table. Retardation was not simulated. Vertical transport was simulated through 5 feet of ash and 5 feet of natural clay above the water table. The model predicted that nitrate-N concentrations would exceed 1 mg/L beneath the golf course site area for a period of 17 years.

Groundwater flow and transport was simulated by GAI using QUICK DOMENICO.xls, a quasi-three dimensional transport model assuming a constant hydraulic gradient. Nitrate concentrations 450 feet away from the source were predicted to be a maximum of 4.2 milligrams per liter (mg/L) nitrate-N, and 3.6 mg/L after a period of 17 years.

Many assumptions and parameter values presented in this report are generally consistent with the modeling described in Sections 6 and 7 of this report. Conclusions of the GAI report regarding offsite contaminant transport were not consistent with the modeling described in this report, because of their assumption that the hydraulic gradient is spatially uniform and a lack of consideration of the impact of the drainage ditch system.

CDM also reviewed the report prepared by URS (2001b). Prior to the construction of the golf course, URS conducted a study to evaluate the leachability of metals from stabilized fly ash and performed modeling to predict concentrations of ash-related constituents in groundwater at the site boundary. This study identified seven chemicals of potential concern. Of these, selenium and arsenic were assessed to be of greatest potential concern. URS used an "Integrated Pathway Model" approach, combining unsaturated zone modeling using EPA's HELP and VLEACH models, combined with groundwater flow and transport in the saturated aquifer using MODFLOW and MT3D. CDM reviewed the HELP model simulations and was able to reasonably recreate the results, as discussed in Section 5.3. URS' modeling resulted in an estimate of 18.9 inches per year of leachate infiltration generated at the site. CDM conducted a similar analysis described in Section 5.2 using updated input parameters that resulted in somewhat lower estimates of infiltration rates.

Assuming that the leachate production rate can be used to approximate the infiltration to shallow groundwater, URS applied the 18.9 inches per year value to the entire 215 acre site, including areas with little or no ash fill and to the pond areas. This assumption generated a total leachate volume approximately twice that estimated by CDM. To simulate migration of the leachate in the saturated zone, URS then performed groundwater flow and transport modeling using MODFLOW and MT3D using a simple one-layer model that does not represent surface water features or groundwater-surface water interaction. Transport parameters used in the URS model assumed less adsorption of arsenic and higher dispersion coefficients than those estimated by CDM.

The data review also included the recent MACTEC report (MACTEC, 2009). MACTEC performed field work and laboratory analyses including groundwater and surface water sampling and water level measurements, soil borings of the ash fill and soil cover. This data was used extensively in CDM's analysis.

The USGS developed a regional groundwater model of the Virginia Coastal Plain area (Heywood, 2009) that provided a reference for off-site hydrological and hydrogeologic conditions used in the groundwater model development for the site described in Section 6. Other USGS reports that provided general background information used in the analyses discussed in this report include Harsh and Laczniak (1990), Laczniak and Meng (1988) and Hamilton and Larson (1988).

4.2 Hydrogeologic Data Review

4.2.1 Aquifer Performance Test Analysis

During November of 2009, CDM conducted an APT at well TW-1, as described in Section 2.3. The APT was performed with a pump capable of pumping approximately 35 gallons per minute (gpm) and was conducted over a three day period. Water level loggers were installed in seven wells (MW-3A, MW-3B, MW-3C, MW-5A, MW-5C, PZ-1, and PZ-2). Wells MW-5A and -5C were monitored for background and are located southwest of the site. **Figure 4-1** shows the locations of the pumped well (TW-

1) and the wells that were monitored. **Table 4-1** shows the well construction details for each of the APT wells installed by CDM. The following figures show the observed water levels that were recorded during the APT.

- MW-3A/MW-3B Area (**Figure 4-2**): A decline in groundwater level was observed in these two wells prior to pumping at TW-1. Following the start of APT pumping, drawdown is observed in both wells. Drawdown is more pronounced in the deeper MW-3B well (42 feet deep) versus the shallower (15 feet deep) MW-3A well.

- PZ-1/PZ-2 Area (**Figure 4-3**): A decline in groundwater level was also observed in these two wells prior to pumping at TW-1. Following the start of APT pumping, drawdown is observed in both wells. Drawdown was more significant at PZ-1 (30 feet from TW-1) than at PZ-2 (60 feet from TW-1). Drawdown was also more pronounced at PZ-1 and PZ-2 than at MW-3A and MW-3B, due to their closer proximity to the pumping well.

- MW-3C (**Figure 4-4**): A small amount of drawdown was observed at MW-3C. This well is screened in the Yorktown aquifer below the surficial aquifer where TW-1 is screened. Due to the relatively small amount of drawdown observed at MW-3C, this well was not analyzed in detail.

- MW-5A/MW-5C Area (**Figure 4-5**): Changes in groundwater level due to the APT were not observed at these two wells located over 4,000 feet from TW-1. The groundwater level at well MW-5A well shows a similar declining trend as observed at MW-3A, MW-3B, PZ-1, and PZ-2, suggesting a change in background hydrologic conditions during the test. The groundwater level at MW-5C appears to be responding to a background stress, possibly from groundwater pumping at a nearby well.

The software program AQTESOLV was used to analyze the results of the APT. AQTESOLV allows for the analysis of multiple types of APTs, including the constant rate test performed at TW-1. AQTESOLV uses the physical layout of the wells (spacing, depth, screened elevations, diameters) and specification of a pumping rate to perform the analysis. This data was based on the information previously shown in Table 4-1. The observed drawdown is also input to AQTESOLV for the software to use to estimate hydraulic properties.

The Hantoush (leaky aquifer) solution technique was used estimate the hydraulic conductivity of the surficial aquifer from the data. Use of a “leaky” type solution was selected to represent the hydraulic impact of semi-confining clay/silt layers above and below the surficial aquifer. **Figure 4-6** shows a conceptual cross-sectional view of the aquifer system as specified in AQTESOLV. The AQTESOLV estimation of horizontal hydraulic conductivity of the Columbia aquifer is shown in **Table 4-2**.

Note that two different estimates of the ratio between horizontal hydraulic conductivity (K_h) and vertical hydraulic conductivity (K_z) were assumed. This assumption had little impact on the analysis results. Additional aquifer conceptualizations (unconfined and confined) as well solution techniques (Theis, Cooper-Jacob) were also analyzed. The results of these solutions generally agreed with the results shown in Table 4-2.

The TW-1 APT analysis indicates that, in general, the horizontal hydraulic conductivity in the area of TW-1 is in the range of 50 to 70 ft/day. This range is consistent with values that are expected for a fine- to coarse-grained sand aquifer. This analysis did not provide sufficient information to assess the ratio between horizontal hydraulic conductivity and vertical hydraulic conductivity with AQTESOLV.