TVA

Tennessee Valley Authority
Kingston Fossil Plant

GROUNDWATER MONITORING PLAN

COAL COMBUSTION BYPRODUCT DISPOSAL FACILITY - PENINSULA SITE

KIF450

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A TVA Quality Assurance Procedure No. ES-41.6 – Groundwater Sample Collection Techniques

1. INTRODUCTION

This Groundwater Monitoring Plan has been prepared to satisfy the requirements of Tennessee Department of Environment and Conservation (TDEC) Rule 1200-1-7 for the Proposed Coal Combustion Byproduct (CCB) Disposal Facility at the Kingston Fossil Plant (referenced hereafter as CCB disposal facility). The CCB disposal facility is located at the base of a peninsula at the confluence of the Clinch and Emory Rivers in Roane County, Tennessee. The CCB disposal facility will extend from the central portion of the peninsula to its southern margin adjacent to the Clinch River. The CCB disposal facility must conform to the Class II landfill regulations promulgated by the Division of Solid Waste Management (DSWM) of TDEC. The Groundwater Monitoring Plan describes procedures and protocols to evaluate the potential impacts from the proposed CCB disposal facility on groundwater quality beneath the Peninsula Site.

1.1 Summary of Site Geology and Hydrogeology

A hydrogeologic evaluation of the CCB disposal facility site was conducted by the Tennessee Valley Authority (TVA) in 2005 (Julian and Boggs, 2005). The evaluation compiled hydrogeologic data collected during previous geotechnical studies and site investigations. Groundwater conditions are currently monitored in five residuum piezometers, nine residuum monitoring wells, and four bedrock monitoring wells. The following is a summary of geologic and hydrogeologic characteristics of the site as presented in Julian and Boggs (2005):

- The CCB disposal facility site is hydraulically bounded on all sides – the Clinch River to the south forms a constant head boundary and the ridge-line to the north and northwest forms a no-flow boundary.
- The uppermost geologic unit at the site is a silty to clayey residuum. Silty alluvium is also occasionally present but is primarily encountered along the low-lying areas at the Site's western margin. The residuum deposits range in thickness between 8.5 to 120 feet. Vertical hydraulic conductivity (K_h) of undisturbed residuum samples ranged from 10^{-4} to 10^{-8} centimeters/second (cm/s).
- Carbonate bedrock, primarily dolomite, of the Knox Group underlies the unconsolidated residuum and alluvium. The Knox Group is regionally characterized as being prone to solution weathering particularly along joints and joint sets, resulting in a highly variable top of rock surface elevation. The top of bedrock surface at the CCB disposal facility is similarly variable, ranging in

elevation from 677 to 851 feet mean sea level (msl) in the disposal area. The bedrock surface dips to the south-southeast.

- Dolines (sinkholes) present within the proposed disposal boundary have been found to be closed and not directly draining into the bedrock. Stable soil conditions have been observed at each of the dolines due to the presence of at least 35 ft. of void-free overburden and no evidence of soil stoping.

- Groundwater flow in the residuum generally follows topography, flowing from the ridge along the northern to northwestern Site boundary to the southeast towards the Clinch River. Saturated thickness of the residuum is variable based on seasonal influences (i.e., recharge via precipitation) and stage of the Emory and Clinch Rivers.

- Groundwater flow direction in the bedrock was not discussed in Julian and Boggs (2005). However, the bedrock flow direction was inferred to be southeasterly from the ridge based on water level measurements collected on March 2, 2006. This conclusion regarding the flow direction is tentative since it is based on only four bedrock monitoring points.

- Downward vertical hydraulic gradients have been documented at the two well pairs closer to the ridge (MW-10A/10B and MW-63A/63B). Downward vertical gradients at well pairs along the central portion of the disposal area have been negligible.

- Zones of varying hydraulic conductivity and flow were observed in six residuum wells and two bedrock wells using an electromagnetic borehole flowmeter (EMFM). In the residuum, zones of higher hydraulic conductivity tended to correlate to sandy intervals; the highest horizontal hydraulic conductivity (K_h) value for the higher zones was measured at $8x10^{-2}$ cm/s. The lowest K_h values were less than 10^{-6} cm/s and correlated with silty clay zones.

- The flowmeter profiles in the bedrock monitoring wells suggest that the epikarst interval (weathered zone near the top of bedrock) is potentially the most transmissive bedrock interval; however, the presence of well-connected fracture zones below the epikarst may also have similar hydraulic conductivity.

1.2 Proposed Groundwater Monitoring System

A groundwater monitoring system will be developed at the CCB disposal facility for the purposes of meeting TDEC monitoring requirements. The groundwater monitoring system is designed to assess the quality of groundwater unaffected by disposal processes and to monitor groundwater quality at the downgradient compliance boundary of the disposal facility. To meet these objectives, the proposed groundwater monitoring system includes upgradient and downgradient monitoring wells located outside of the projected limit of land disturbance of waste disposal development and operation. The limit of disturbance, therefore, becomes the effective groundwater compliance boundary.

The existing site residuum and bedrock monitoring wells lie within the footprint of the proposed disposal area, and thus, will not be used in the groundwater monitoring system. These wells will be plugged and abandoned in accordance with TDEC regulations prior to commencing disposal activities.

The proposed monitoring system includes upgradient and downgradient monitoring wells installed in both the residuum and bedrock units. Monitoring of both hydrogeologic units is warranted for two reasons: 1) the units are hydraulically connected with documented downward vertical flow potentials, and 2) groundwater flow in both units discharges into the Clinch River. Figure 1-1 depicts the 10 proposed monitoring well pair locations, their relation to the groundwater compliance boundary, the existing residuum monitoring wells and piezometers, and the residuum potentiometric surface from the March 2, 2006 gauging event. Residuum and bedrock wells at proposed pair locations are designated with "A" and "B" suffixes, respectively. The proposed locations may be shifted in the field depending upon access conditions.

The proposed disposal boundary will extend to the base of the ridge along the north and northwest Site boundary. Well pair MW-1A/1B will serve as an upgradient monitoring location for the Phase I disposal area and will be situated near the top of the ridge. Groundwater conditions upgradient of the Phase II disposal area will be evaluated at the MW-2A/2B well pair, located slightly below the ridge top. Although residuum locations are tentatively proposed at these two upgradient locations, it is possible that residuum monitoring in these locales may not be feasible since unsaturated conditions may be present in the thinly-developed residuum near the ridge top. Well pairs MW-3A/3B through MW-10A/10B are all intended to monitor groundwater quality downgradient from both the Phase I and II disposal areas.

1.2.1 Monitoring Well Design and Construction

The proposed monitoring well borings will be advanced using a combination of drilling technologies that are commonly used in the region, such as hollow-stem auger, air rotary drilling, and bedrock coring. Selection of the drilling technology will be made by TVA based on a number of important considerations such as site accessibility and appropriate drilling technology. The proposed monitoring wells will be constructed of 2-inch diameter PVC well screen and casing and shall be installed in 6-inch diameter boreholes in order to comply with TDEC monitoring well regulations. The design of each type of monitoring well is discussed separately below.

Residuum Monitoring Wells

The residuum monitoring wells will be constructed in the manner depicted in Figure 1-2. The residuum well borings will be advanced to bedrock refusal, which was found to vary between 35 and 59 feet below ground surface (bgs) during previous investigations at the Site. The well screen shall have a minimum length of 10 ft. and a slotted interval of 0.010 inches. The well will be set on a 6-inch thick footing of environmental-grade filter pack sand (20/40 grain size unless otherwise noted). The top of the filter pack will extend a minimum of six inches above the top slot of the well screen. A minimum 2-foot bentonite seal will be placed on top of the filter pack. The filter pack material and bentonite seal will be placed in the annulus through a 1-inch PVC tremie pipe when practical. The remaining annulus will be filled with a cement-bentonite grout.

The monitoring wells will be completed above grade with a stickup. Each well will have a vented PVC cap and a lockable, steel outer casing secured in a 4 ft. x 4 ft. concrete pad. The steel casing will be protected by four, 6-inch diameter steel bollards installed to a 4-foot height at the four corners of the concrete pad. The bollards will be set in concrete approximately 4 feet bgs.

Upon completion each well will be developed using a combination of methods such as air lift, surging, and pumping. After development the wells will be surveyed by a licensed surveyor for location and elevation of the top of casing.

Bedrock Monitoring Wells

Groundwater monitoring in the bedrock will utilize a single monitoring interval unless field observations indicate that multi-level monitoring is warranted. Bedrock monitoring wells will be constructed in the manner depicted in Figure 1-3, unless field conditions necessitate modifications. Bedrock borings will be advanced into the upper 20-30 feet of the bedrock to target the more permeable epikarst zone. The existing bedrock monitoring wells have total depths that vary between 61 and 104 feet bgs. The total depth of the proposed bedrock monitoring wells will be determined in the field based on observations during drilling such as fluid loss or gain, the presence of voids or fractures, or overall rock competency based on penetration rate. A 10-inch diameter borehole will be advanced through the residuum and into the upper 2 to 5 feet of competent bedrock. An 8-inch diameter, steel surface casing will be installed and grouted in place using a cement-bentonite grout, which will be allowed to cure for 24 hours. Bedrock borings will be advanced using drilling methodologies such as air rotary or wire-line coring to ultimately produce the 6-inch annular diameter required by TDEC for monitoring well borings.

The well screen shall have a minimum length of 20 feet to account for seasonal fluctuations in the groundwater levels. The screen will have a slotted interval of 0.010 inches. The bedrock well shall be completed, developed and surveyed in the same manner as the residuum monitoring wells, discussed previously above.

2. GROUNDWATER MONITORING PROGRAM

The following section discusses the Groundwater Monitoring Program that is proposed for the Site in accordance with the TDEC Solid Waste regulations established in Rule 1200-1-7-.04.

2.1 Detection Monitoring Program

Sitewide groundwater monitoring will consist of a Detection Monitoring Program. The requirements of Rule 1200-1-7-.04 state that the Detection Monitoring Program includes quarterly sampling during the landfill's first year of operation to establish a statistical baseline and initial background concentrations in the wells before waste is placed in the facility. Thereafter, the Detection Monitoring Program is reduced to semi-annual sampling. During the quarterly and semi-annual sampling events, groundwater samples from the proposed monitoring wells (Figure 1-1) will be analyzed for the 17 inorganic constituents listed in Table 2-1. As stipulated in Rule 1200-7-.04, none of the volatile organic compounds listed in Appendix I of TDEC Solid Waste Regulations are required in the Detection Monitoring Program for Class II disposal facilities.

Table 2-1: Inorganic Constituents and Analytical Methods for Detection Monitoring

Parameter	EPA Method
Antimony	6010/6020
Arsenic	6010/6020
Barium	6010/6020
Beryllium	6010/6020
Cadmium	6010/6020
Chromium	6010/6020
Cobalt	6010/6020
Copper	6010/6020
Fluoride	6010/6020
Lead	6010/6020
Mercury	7470/7471
Nickel	6010/6020
Selenium	6010/6020
Silver	6010/6020
Thallium	6010/6020
Vanadium	6010/6020
Zinc	6010/6020

Adapted from Appendix I (TDEC 1200-1-7.04)

Upon completion of the quarterly events conducted in the first year, the groundwater concentrations of the constituents in Table 2-1 will be evaluated to determine a representative background concentration. These background concentrations, approved by TDEC, will then be used to screen all subsequent groundwater samples collected during the Detection Monitoring Program.

Field procedures for all groundwater sampling events are discussed in Section 3.0.

2.1.1 Reporting

Within 60 days of the end of each sampling event, TVA will submit a report to TDEC that serves as a summary of the sampling event procedures, analyses and results, and statistical evaluation. As specified in TDEC's *Ground Water Monitoring Guidance for Solid Waste Landfill Units (GW Monitoring Guidance Document),* the report will include the following items:

1. Description of sampling procedures, field measurements (i.e, water quality parameters), purge volumes, dates and times of sampling, and weather conditions;
2. Elevation (mean sea level) of each monitoring well's top of casing and ground surface;
3. Groundwater flow direction and rate across the site;
4. Scaled site basemap that includes all monitoring well locations, the potentiometric surface elevation for the sampling event, the property boundary, and the active and closed fill areas;
5. Summary of sampling parameters and analysis method;
6. Copies of chain of custody forms and laboratory reports;
7. Tabulated sample results compared against background groundwater quality concentrations and groundwater protection standards;
8. Summary of the statistical method used for determining a statistically significant increase (SSI) (meeting the requirements of Rule 1200-1-7-.04) and the results of the statistical analysis;

9. Scaled site basemap that presents the location of each monitoring well and concentrations of the constituents/parameters that were found to statistically exceed background concentrations or groundwater quality protection standards;

10. A schedule for the next sampling event; and,

11. A certification meeting the requirements of Rule 1200-1-7.02(2)(a) 7, 8, and 10.

2.1.2 Statistical Data Evaluation

In accordance with the Detection Monitoring Program requirements, TVA will evaluate the semi-annual results to determine if any constituent exhibits a SSI in concentration. Statistical analyses will be performed using non-parametric prediction intervals (NPI) with an intra-well basis (Gibbons 1990, 1994). This statistical method is currently being used by TVA for assessing groundwater compliance data from the GCB Disposal Facility at KIF and is discussed in detail in Appendix E of the report prepared by Boggs (2005). In general, the NPI method assumes that the distribution of baseline and future compliance sampling data are identical in the absence of contamination from a disposal facility. An upper prediction limit (UPL) for each constituent is determined based on the maximum concentration detected during the baseline sampling period. If the UPL is exceeded during a subsequent sampling event, the well is independently resampled a statistically determined number of times to achieve the desired level of confidence. If all the resample measurements exceed the UPL, the original exceedance is considered an SSI. If at least one of the resample results is below the UPL, the original exceedance is considered insignificant.

If an SSI is determined, TVA will comply with the requirements of Rule 1200-1-7-.04 which requires:

1. notifying TDEC within 14 days indicating which constituents have shown an SSI;

2. establishing an Assessment Monitoring Program within 90 days; or,

3. demonstrating, at TVA's discretion, that the SSI is the result of contamination from source other than the proposed CCB disposal facility or is the result of an error in sampling, analysis, statistical methods, or natural variability.

If the demonstration is not made within 90 days, an Assessment Monitoring Program must be established.

2.2 Assessment Monitoring Program

Within 90 days of triggering an Assessment Monitoring Program, TVA will sample groundwater from the groundwater monitoring system. TVA proposes that these samples be analyzed for the Appendix I inorganic constituents and any parameters specified by TDEC as being characteristic of the waste, but not for the Appendix II constituents of Rule 1200-1-7-.04. Due to the composition and geochemical reactivity of the disposed gypsum, analysis of the Appendix II constituents is unwarranted since they are primarily organic compounds, such as volatile organics, semi-volatile organics, pesticides, and PCBs. As a result, the remaining discussion in this section will refer to the Appendix I constituents and any parameters specified by TDEC as being characteristic of the waste as the Assessment Monitoring Constituents.

The Assessment Monitoring Program consists of Phase 1, 2, and 3 as stipulated in TDEC's GW Monitoring Guidance Document. Each phase is described separately below.

2.2.1 Phase 1

Phase 1 consists of two separate sampling events and several reporting requirements.

Initial Assessment Sampling Event – During this sampling event, all downgradient monitoring points are sampled and analyzed for the Assessment Monitoring Constituents. TVA may request deletion of some constituents if justification can be provided that they should not be reasonably expected to be derived from waste contained in the landfill. This request must be made within the first 30 days of the 90-day timeframe.

Background Sampling for Identified Assessment Monitoring Constituents – This Phase 1 task entails four independent samplings of upgradient and downgradient monitoring points for the Assessment Monitoring Constituents detected in the Initial Assessment Sampling Event that had not been previously detected. The four events will be used to establish background groundwater concentrations for any Assessment Monitoring Constituents without a published background concentration.

Additionally, TVA must:

1. notify TDEC of all detected Assessment Monitoring Constituents within 14 days of receipt of results; and
2. submit a summary report of the results that complies with the reporting requirements of Section 2.1.1 above.

If the Assessment Monitoring Constituents are below groundwater protection standards, TVA will proceed to Phase 2; if any Assessment Monitoring Constituents exceed groundwater protection standards, TVA will notify TDEC within 14 days of the exceedances and proceed to Phase 3 (Groundwater Quality Assessment Program).

At the end of Phase 1, TVA may also submit a written request for alternative groundwater protection standards for constituents without MCLs. The request must satisfy criteria set forth in Rule 1200-1-7-.04(7)(a) ii.

2.2.2 Phase 2

Phase 2 requires two semi-annual sampling events. The first sampling event includes all Appendix I inorganic constituents, any additional approved parameters, and any Assessment Monitoring Constituents previously detected. The second sampling event includes all Assessment Monitoring Constituents and any other approved parameters. As with Phase 1, TVA may request in writing 60 days before sampling to delete any Assessment Monitoring Constituents that are not reasonably expected to be derived from gypsum disposed at the facility.

Each semi-annual sampling event will be summarized in a report that adheres to the requirements discussed previously in Section 2.1.1. If all Assessment Monitoring Constituents are below their groundwater protection standards, the site remains in Phase 2 until these constituents are shown to be statistically below their representative background concentrations for two consecutive sampling events. If any Assessment Monitoring Constituents exceeds groundwater protection standards, TVA must notify TDEC within 14 days of the exceedance and proceed to Phase 3 (Groundwater Quality Assessment Program).

2.2.3 Phase 3 - Groundwater Quality Assessment Program

TVA will submit a Groundwater Quality Assessment Plan (GWQAP) to TDEC within 45 days of discovering an exceedance of a groundwater quality protection standard by an Assessment Monitoring Constituent. Furthermore, TVA must initiate a corrective measures assessment within 90 days of discovering the exceedances as stipulated in Rule 1200-1-7-.04(7)(a)7. During this time, TDEC is authorized to require TVA to take any measure necessary to protect human health and the environment. TVA may not return to Detection Monitoring until the Assessment Monitoring Constituent concentrations are below groundwater protection standards for 3 years or a negotiated timeframe approved by TDEC.

The GQWAP must include the following tasks:

1. Determine a) if solid waste or its constituents have entered groundwater, b) the rate and extent of waste migration or its constituents in groundwater, and c) the concentration of the waste or its constituents in groundwater;

2. Specify the number of additional groundwater sampling locations and the depth(s) of additional well(s) to define the horizontal and vertical extent of release (at least one monitoring well must be installed at the compliance boundary in the direction of migration);

3. Identify domestic and commercial water use sources within a one-mile radius from the center of the disposal facility and report the findings of this survey (i.e., topographic map with sources identified by name, address, coordinates and phone numbers) to TDEC with 45 days; and

4. Conduct quarterly sampling of selected groundwater monitoring points for analysis of parameters with SSIs.

In accordance with Rule 1200-1-7-.02(2)(a) 7, 8, and 10, a qualified groundwater scientist and TVA representative must certify the GQWAP.

As the GQWAP is being developed and approved and throughout its implementation, TVA will conduct quarterly sampling and analysis of all monitoring points and submit results in quarterly reports. The analytes for each quarter include:

<u>Quarters 1 and 3</u>: all Assessment Monitoring Constituents (i.e., Appendix I inorganics, waste-characteristic constituents, and any additional approved parameters); and

<u>Quarters 2 and 4</u>: all constituents with an SSI.

3. GROUNDWATER SAMPLING AND ANALYSIS METHODS

The following section briefly summarizes the primary components of the groundwater sampling and analysis plan to be utilized at the CCB disposal facility Site. These components are described in detail in TVA's Quality Assurance Procedure *Groundwater Sample Collection Techniques* (Attachment A); the document contains requirements for initial groundwater level measurements, groundwater sample collection, preservation, shipment, record-keeping, chain of custody, quality assurance and quality control, and copies of groundwater quality data field worksheets and other pertinent forms.

3.1 Groundwater Level Gauging

Each sampling event will commence with a Sitewide groundwater level gauging event to provide a "snapshot" of groundwater head distribution. These measurements will be collected to the nearest 0.01 ft. and will be used to prepare Sitewide potentiometric surface maps of residuum groundwater and bedrock groundwater to represent groundwater conditions at the time of sampling. The groundwater level data are documented on the Groundwater Level Measurements Form included in Attachment A.

3.2 Groundwater Purging and Sampling

The volume of stagnant groundwater inside each monitoring well will be calculated and removed by purging prior to sampling to ensure that a representative groundwater sample is obtained. The appropriate purging equipment (i.e, bailers, submersible pumps, bladder pumps, etc.) will be chosen based on factors such as groundwater level depths, turbidity, and well recharge. At least two well volumes will be removed from each well during purging while minimizing the amount of water level drawdown to the extent practicable. Wells with poor recharge may be completely purged dry and sampled upon recovery within a 24-hour period. The total volume purged at each well will vary based on its recharge rate and the chemical stability of the groundwater water quality field parameters shown in Table 3-1. The field instruments used to collect water quality data will be appropriately calibrated each day in accordance with TVA's policies and procedures and the manufacturer's instructions.

Table 3-1: Field Parameters

Parameter	Method	Purpose
Conductivity	Field instrument with sensor and probe	Determine groundwater geochemical stability
Dissolved Oxygen (DO)	Field instrument with sensor and probe	Determine groundwater geochemical stability
Temperature	Field instrument with sensor and probe	Determine groundwater geochemical stability
pH	Field instrument with sensor and probe	Determine groundwater geochemical stability
Redox Potential (ORP)	Field instrument with sensor and probe	Determine groundwater geochemical stability
Depth to Water	Water level indicator	Determine amount of water level drawdown
Acidity/Alkalinity	Standard titration method	Geochemical parameter; one-time measurement

All field parameters except acidity/alkalinity are recorded at regular time or volume intervals during purging on a Groundwater Data Field Worksheet (Chemical Data) (shown in Attachment A) to monitor the variability in groundwater chemistry. Once two well volumes have been purged and groundwater pH, conductivity, temperature, dissolved oxygen (DO), and redox potential (ORP) parameters are stable (i.e., within 5% during three consecutive readings with no apparent upward or downward trends), it can be reasonably assumed that groundwater chemistry is consistent and that a sample would be representative of conditions in the aquifer; otherwise, purging continues until these parameters stabilize as specified above. Groundwater sampling generally uses the same equipment that purged the well, unless that equipment is not practical for sampling (i.e., a high discharge pump that cannot reduce flow enough to carefully fill sample containers). Groundwater samples will be unfiltered and collected in appropriate, pre-preserved sample containers. The containers will be labeled with the well name, date/time of sample collection, requested analyses, and preservative. This information will also be recorded on a chain of custody form after sample collection. A final reading of water quality parameters will be conducted immediately after sample collection but not from the sample aliquot itself.

The sample containers will be stored on ice at 4°C inside a cooler. The sample containers will be secured inside the cooler to prevent breakage while in transit to the receiving laboratory. The samples will be shipped to a Tennessee certified analytical laboratory with adequate lead time to ensure holding times are met.

3.3 Laboratory Analyses

During Detection Monitoring, the analytical laboratory will conduct analyses for the 17 Appendix I inorganic constituents shown previously in Table 2-1. With the exception of mercury, the inorganics will be analyzed by EPA Method 6010/6020. Mercury will be analyzed by EPA Method 7470/7471.

3.4 Recordkeeping

A project field logbook will be maintained by TVA personnel or their representative during each groundwater sampling event. The logbook will be used to record pertinent data and observations throughout the entire sampling event. The field logbook are maintained by the lead engineer and will remain in the office at all times when not in use.

Field forms for all sampling activities are included as part of Attachment A. These include:

- Groundwater Quality Data Field Worksheet (Chemical Data) – TVA 30066A
- Groundwater Quality Data Field Worksheet (Physical Data) – TVA 30066B
- Groundwater Level Measurements (Field) – TVA 11552
- Acidity and Alkalinity Worksheet – TVA 30533

4. REFERENCES

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TDEC-DSWM. Ground Water Monitoring Guidance for Solid Waste Landfill Units.

FIGURES