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NRS Treatability Test Work Plan

TVA Gallatin Fossil Plant
Sumner County, Tennessee

Revision 0
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Quality information

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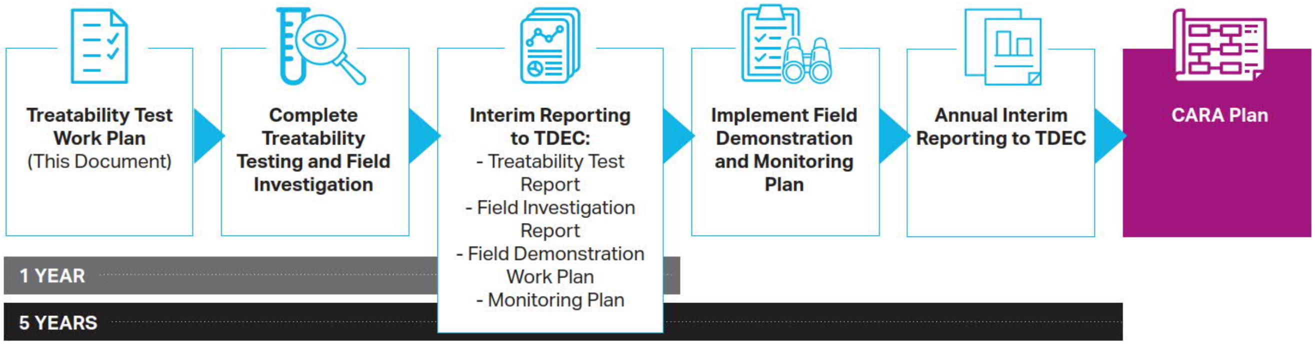
Executive Summary

The following work plan details the proposed treatability testing to be performed in response to the Tennessee Department of Environment and Conservation (TDEC) Commissioner's Order Number OGC19-0004 (the Order). In accordance with the Order, TVA will conduct a laboratory treatability test and field demonstration aimed at adjusting pH to sequester metals along the Non-Registered Site (NRS) boundary adjacent to the Cumberland River at the Gallatin Fossil Plant.

The treatability test and field demonstration will be completed over a five-year duration following TDEC approval of this work plan. The overall objective of the project is to perform field investigation and remedial testing and evaluation sufficient to develop a plan to meet groundwater protection standards (GWPS) at the NRS boundary compliance points. This work builds on previous studies which showed promise in the use of amendments to reduce metal concentrations in groundwater by adjusting pH.

Upon completion of a successful treatability test and field demonstration at the NRS, TVA will then develop a Corrective Action/Risk Assessment (CARA) Plan presenting recommendations for the closure method and groundwater remediation at the NRS. The following presents a general flow schematic for completion of the project, beginning with the treatability test and concluding with the CARA Plan.



This Treatability Test Work Plan presents the first step of the project, detailing the scope of work for:

- A focused field investigation, described in Section 3, to collect samples and data required to complete the treatability test and properly design the field demonstration, and
- An extensive treatability test, described in Section 4, to evaluate remedial amendments that may be used to meet GWPS at the site.

The treatability testing will include a series of progressively more complex tests, whereby a broad list of potential remedial amendments is gradually reduced to a smaller list of reagents that show promise for remediation under field conditions. The treatability testing will progress from:

- Simple titration testing, which tests the remedial amendments with site groundwater; to
- Microcosm testing, which tests the remedial amendments with site groundwater and soil; to
- Column testing, using site groundwater and soil to simulate field conditions during application of remedial amendments.

The testing approach, presented graphically on Figure 4-1, is aimed at narrowing the potential remedial amendments based on success in simpler tests, before performing more complex tests, which will also utilize more rigorous analytical testing to find reagents that are most likely to meet performance standards in the field. A successful treatability test will identify at least one reagent that:

- Is appropriate for safe handling and application at field scale at the NRS in the vicinity of the Cumberland River,
- Reduces metals concentration to below GWPS in groundwater,

- Sequesters metals over a sufficient time that it allows practical maintenance of a field-scale remedy,
- Does not alter aquifer geochemistry in such a way as to mobilize non-target metals at concentrations approaching GWPS at a point-of-compliance, and
- Has the potential to be utilized in a long-term cost-effective remedial treatment in terms of capital cost and operations and maintenance.

In addition to describing the treatability test program, this work plan provides the concept and framework for a successful field demonstration. The feasibility of all remedial options will be considered, including both source control and remediation at the NRS boundary to help develop the comprehensive long-term solution for the site. Remedial solutions being considered for the field demonstration include direct injection of remedial amendments, a permeable reactive barrier, and in-situ stabilization.

TVA estimates the treatability test and field investigation can be completed in approximately one year. Following completion of the work, the following interim submittals will be prepared for TDEC review and approval before beginning the field demonstration:

1. A Treatability Test Report providing the results of the laboratory testing and recommendations for remedial amendments,
2. A Field Investigation Report presenting the findings from the investigation and updates to the conceptual site model (CSM), as appropriate,
3. A Field Demonstration Work Plan presenting the scope of work and design of the field demonstration, and
4. A Monitoring Plan providing the proposed monitoring to be completed during performance of the field demonstration.

Upon TDEC approval, the field demonstration will be implemented through one or more pilot-scale remedial efforts at the NRS. During performance of the demonstration, TVA proposes annual interim reporting on the progress toward meeting GWPS.

1. Introduction

AECOM has prepared the following Treatability Test Work Plan on behalf of the Tennessee Valley Authority (TVA) to detail the treatability testing being performed in response to the Tennessee Department of Environment and Conservation (TDEC) Commissioner's Order Number OGC19-0004 (the Order). The Order requires that TVA conduct a laboratory treatability test and field demonstration aimed at adjusting pH to sequester metals along the Non-Registered Site (NRS) boundary adjacent to the Cumberland River at TVA's Gallatin Fossil Plant (GAF) to evaluate whether such actions can result in achievement of groundwater protection standards (GWPS). The Order also requires development of a field demonstration and monitoring plan and a Corrective Action/Risk Assessment (CARA) Plan for closure of the NRS and remediation of groundwater to be completed following the field demonstration. The requirements of the Order and the performance of the field demonstration will be fulfilled following completion of the treatability test described herein. However, a general overview of the anticipated field demonstration project is included here to provide context for performance of treatability testing and to support the performance of an accompanying field investigation, which will be used to help develop the design for the field demonstration.

The Order requires submittal of this work plan within 90 days of the effective date of the Order, which was July 13, 2019. The Order further requires that the treatability test and field demonstration project be completed within five years of TDEC's approval of this work plan. A schedule of activities for the overall project is provided in Section 7.

1.1 Background

The NRS is an approximately 70-acre closed surface impoundment historically used for the disposal of an estimated 2.3 million cubic yards of coal combustion residuals (CCR) prior to 1970. The location of GAF is depicted on Figure 1-1, and the location of the NRS within GAF is depicted on Figure 1-2. The NRS includes a perimeter dike and a series of interior dikes that subdivide the NRS into four sections, as depicted on Figure 1-3. In 1995, TVA developed a Closure Plan for the NRS. The NRS Closure Plan was approved by TDEC in 1997. During 1997 and 1998, the NRS Closure Plan was implemented, including placing a 1-foot soil cover over areas where vegetation was not already well established, lining the coal yard runoff ditch with concrete to minimize groundwater recharge, and plugging the remaining spillway to the Cumberland River with concrete.

During groundwater monitoring activities for the NRS, concentrations of beryllium (Be), cadmium (Cd), and nickel (Ni) were detected in groundwater samples collected from monitoring well 19R at concentrations greater than TDEC GWPS. In 2015, additional investigation and monitoring activities were initiated to determine the conditions that resulted in the observed GWPS exceedances. The findings were compiled into two data packages in 2015 that were ultimately included as attachments to the April 2017 Draft Environmental Assessment Report (EAR; TVA 2017a).

In 2016, TVA initiated the TDEC-approved Environmental Investigation Plan (EIP), which included additional work in the vicinity of the NRS, including assessment of CCR thickness and extent, evaluation of dike stability, and installation and sampling of monitoring wells. The results have been provided in several submittals to TDEC (i.e., the EAR [TVA 2017a]; EAR Interim Sections [TVA 2017b]). Additional environmental investigation activities are ongoing, primarily in other areas of GAF, and a Final EAR will be issued following the completion of those investigation activities. The investigation activities found that acidic groundwater and elevated metals concentrations were limited to the alluvial aquifer and were not found in bedrock groundwater or ash pore water, which appear to have sufficient buffering capacity to maintain circumneutral or alkaline pH.

The 2015 data packages and Draft EAR indicated that the source of the GWPS exceedances at the NRS did not appear to be associated with CCR, but rather with disposal of pyrite, which oxidizes to form acid in the presence of water and oxygen. The acidic conditions have resulted in the dissolution of metals and the transport of dissolved metals through the alluvium beneath the NRS, such that GWPS for beryllium, cadmium, and nickel are exceeded in places along the downgradient boundary of the NRS. While the NRS is not subject to the federal CCR rule, TDEC has also observed that CCR Rule GWPS have been exceeded for cobalt and lithium at well 19R. In 2003, TDEC approved an evaluation by TVA that concluded the cobalt in groundwater at the NRS is naturally occurring, associated with cobalt in the soils in the area, and is not a release from the NRS. The draft EAR concluded that the use of a pH adjustment strategy appears to be a feasible and effective groundwater corrective action technology to mitigate potential GWPS exceedances in the alluvium at the NRS.

Preliminary treatability testing was performed in 2018 to test remedial amendments that could remove dissolved beryllium, cadmium, and nickel from NRS groundwater samples and to obtain additional data necessary to develop additional pre-design studies. The preliminary treatability testing assessed five amendments: three strong bases (i.e., sodium hydroxide [NaOH], EnviroBlend® [EB], and AQUAMAG®) and two combination reagents (i.e., zero valent iron [ZVI] and FerroBlack® [FB-H]) that alter pH and/or oxidation-reduction potential (ORP). The preliminary treatability testing also looked at the nature of solids that precipitated during testing and the stability of those precipitates. The results of the treatability testing indicated that NaOH, EB, and FB-H were successful at reducing cadmium, beryllium, and nickel concentrations in groundwater samples. At the conclusion of the preliminary treatability test, it was recommended that additional treatability testing be performed using site soil and incorporating additional site data to support the design and implementation of an *in-situ* pilot study. The results of the preliminary treatability testing are provided in Appendix A.

On June 13, 2019, TDEC issued the Order requiring that TVA perform a treatability test and field demonstration to effect remediation of groundwater such that GWPS are met along the NRS boundary at compliance points adjacent to the Cumberland River. The Order also requires the submittal of a monitoring plan prior to the implementation of the field demonstration project and that a Corrective Action/Risk Assessment (CARA) Plan be completed following the demonstration project to develop a comprehensive remedial approach for the NRS.

1.2 Objectives

The objective of the laboratory treatability test and subsequent field demonstration is to determine whether pH and geochemical conditions can be adjusted in alluvial groundwater at the NRS and if such an adjustment can be an effective method to meet GWPS at the NRS boundary compliance points.

To meet this objective, specific data quality objectives were developed for the laboratory treatability test, field demonstration program, and field investigation, as provided in Sections 3, 4, and 5, respectively.

1.3 Work Plan Organization

This treatability work plan is organized as follows:

Section 2 presents the conceptual site model (CSM), describing the site conditions that potentially produce the elevated metals concentrations in groundwater.

Section 3 presents the elements of a planned field investigation to provide supplemental data for the treatability test and help develop design parameters for the field demonstration project.

Section 4 presents the details of the laboratory treatability testing proposed as part of this work plan. This section describes the various laboratory test objectives, procedures, and remedial amendments being evaluated as part of the planned treatability test.

Section 5 presents an overview of the anticipated field demonstration project. Because the exact nature and design of the field demonstration project will be dependent on the results of treatability testing and field investigation described herein, the description of the field demonstration is necessarily general in nature at this time. This section provides a list of field demonstration technologies under consideration, the areas where the technologies might be pilot tested, and considerations for design and evaluation of potential remedial technologies.

Section 6 identifies the reports and subsequent plans to be submitted in response to the Order following completion of the treatability testing and field investigation activities described herein.

Section 7 presents an anticipated schedule of activities for the treatability test, field demonstration project, and development of a CARA Plan for the NRS.

2. Conceptual Site Model

The following section presents the current CSM for the NRS and the acidic conditions and metals concentrations detected in groundwater in the vicinity of the NRS.

2.1 Physical Characteristics

2.1.1 Geologic Units Underlying the NRS

CCR material (ash) in the NRS is underlain by unconsolidated deposits of fine-grained alluvium, fill material, and alluvium/fill mix; and bedrock composed of Ordovician limestone units. The juxtaposition of the geologic units underlying the NRS area is shown conceptually in cross sectional view on Figure 2-1. The primary component of the unconsolidated deposits is a low-permeability alluvium, comprised of clay and silt with isolated sand stringers.

The unconsolidated deposits range in thickness from approximately 10 to 60 feet in the NRS area. These unconsolidated deposits form the uppermost saturated unit beneath the NRS. Portions of the unconsolidated deposits have potentially been affected by site activities and are the subject of bench-scale and field-scale remediation testing in this Work Plan.

The Ordovician limestones subcrop beneath the unconsolidated deposits. The Lebanon Limestone is the primary bedrock unit underlying the unconsolidated deposits in the NRS area. The younger Lower Carters Limestone directly overlies the Lebanon Limestone in the GAF area, but it has been eroded in the NRS area and is largely absent. The Lower Carters Limestone subcrops only along the northeast boundary of the NRS (Figure 2-1).

The depth to saturated unconsolidated deposits underlying the NRS ranges from approximately 10 to 50 feet bgs. Groundwater occurrence in the bedrock units is limited to fracture zones. The Lower Carters Limestone is predominately non-water bearing, based on drilling conducted to date, in the small area where it subcrops beneath the NRS. Based on borings and wells drilled across the GAF site, there are two fracture zones in the Lebanon Limestone, designated the L1 and L2 fracture zones, located approximately 35 feet and 75 feet below the Carters/Lebanon contact, respectively. The L1 and L2 fracture zones have not been easily distinguished in the NRS area, and wells screened in Lebanon fractures typically yield limited groundwater. At one location (well GAF-526L), a deeper Lebanon fracture zone was found to be water-bearing.

2.1.2 Groundwater Flow Direction in the NRS

Within GAF, saturated unconsolidated deposits exist in an area primarily limited to the lower (southern) portion of the peninsula, which includes the NRS area. Groundwater flows from a groundwater high in the vicinity of the coal yard in a radial, but predominantly southwestward direction beneath the NRS, following the ground surface topography toward the Cumberland River, the discharge channel south of the NRS, and the coves at the northern end of the NRS. Figure 2-2 shows the groundwater potentiometric surface contours in the unconsolidated deposits and the extent of saturation in the unconsolidated deposits. The saturated thickness of the unconsolidated deposits ranges from approximately 10 to 40 feet beneath the NRS footprint.

Figure 2-2 also shows the groundwater elevation in wells screened in bedrock underlying the unconsolidated deposits for comparison. Groundwater has not been encountered during drilling in the Carters Limestone beneath the NRS or in the coal yard area. Groundwater occurs in the Carters Limestone just north of these areas, as shown on Figure 2-2. As noted above, wells screened in the Lebanon Limestone in this area typically have poor yield.

The phreatic water surface elevation measurements in wells screened in ash within the NRS measured on June 10, 2019, where available, are indicated on Figure 2-2 for comparison to groundwater elevations in the underlying geologic units. The phreatic surface elevation in the ash typically varies more seasonally and spatially than the underlying units. Depending on the location and time of year, the phreatic surface elevation in the ash can be higher than the surrounding groundwater elevation and appears to be perched on the low permeability unconsolidated deposits in some locations.

The highest groundwater elevations are observed in the coal yard area (Figure 2-2). For the June 10, 2019 measurement period, the highest groundwater elevations (approximately 490 feet above mean sea level [msl]) were observed at wells GAF-440U and GAF-441U, which are screened in unconsolidated deposits. The groundwater elevation at well GAF-441U has been as high as 494 feet msl (in March 2019). The groundwater elevation in Lebanon Limestone well GAF-441L, located adjacent to well GAF-441U, is approximately 1 foot lower (489 feet msl on June 10, 2019), indicating a downward hydraulic gradient. A consistent downward hydraulic gradient has been observed at this well pair location over the past several years.

Due to the high groundwater elevations and downward hydraulic gradient, the coal yard area appears to be a groundwater recharge area. Continued groundwater monitoring is proposed to further assess groundwater recharge in this area and the effect of ongoing changes to plant operations, including stormwater management and decommissioning of the ash ponds, on site hydrogeology.

Figures 2-3 and 2-4 show NRS hydrogeologic conditions in cross sectional view along transect flow lines A-A’ and B-B’ (shown on Figure 2-2). Hydrogeologic cross section A-A’ (Figure 2-3) illustrates groundwater flow in the unconsolidated deposits and Lebanon Limestone between the coal yard and the Cumberland River, which is the regional groundwater discharge zone. Hydrogeologic cross-section B-B’ (Figure 2-4) illustrates the geologic materials between the coal yard and the discharge channel.

2.1.3 Groundwater Flow Rates in Unconsolidated Material

Groundwater flow rates (average linear velocity) are estimated using representative values of hydraulic conductivity, hydraulic gradient, and effective porosity for the saturated unconsolidated deposits. TVA and Arcadis (2014) previously estimated a groundwater flow rate of 3.7 feet/year in the native unconsolidated deposits (alluvium) at the NRS, based on a hydraulic conductivity of 4.1E-05 cm/s (geometric mean of values from 15 alluvial monitoring points using various hydraulic testing methods), a hydraulic gradient of 0.0172 feet/feet, and an assumed effective porosity of 0.2.

A lower groundwater flow rate of 0.8 feet/year is estimated for the unconsolidated deposits using more recent data including a hydraulic conductivity of 1.9E-06 cm/s (geometric mean of slug test results from NRS wells GAF-448U, GAF-441U, and 22; all screened in the unconsolidated deposits), a hydraulic gradient of 0.04 feet/feet (estimated along flow lines A-A’ and B-B’ on Figure 2-2), and an assumed effective porosity of 0.1 to represent the clayey alluvium that is the predominant component of the unconsolidated deposits.

Hydraulic conductivity profiling conducted by AECOM for TVA in 2015 in the NRS area revealed occasional stringers of higher permeability sand in the NRS unconsolidated material. These layers appear discontinuous between borings but may affect local groundwater flow.

2.2 Water Quality/Chemistry

Wells sampled routinely in and around the NRS include five compliance monitoring wells, which are sampled quarterly, and nine additional wells sampled under the EIP. The five compliance wells include well 19R (unconsolidated) paired with well 26 (Lebanon), well 20 (unconsolidated) paired with well 27 (Lebanon), and background well 22 (unconsolidated). The additional wells sampled for the EIP are wells GAF-438L, GAF-441U, GAF-441L, GAF-444U, GAF-445L, GAF-447U, GAF-448U, GAF-448L, and GAF-526L (Figure 2-2).

During the 2015 NRS Phase 1 and 2 investigations, 20 samples of alluvial groundwater and ash pore water were collected during direct push drilling and analyzed in the field for pH. The samples were collected from zones with elevated soil pH (based on field paste pH analysis) and zones with higher hydraulic conductivity (based on the hydraulic profiling tool [HPT] results).

Figure 2-5 provides an overview of the distribution of groundwater and ash pore water sampling locations that have historically displayed a pH lower than 5 or at least one metal concentration result that is greater than the GWPS. The vertical distribution of pH and metals are shown in cross sectional view on Figures 2-3 and 2-4.

Some key observations on the metals and pH distribution in water are as follows:

- The occurrence of low pH (<5) water is limited to groundwater in the unconsolidated deposits. No occurrences of low pH water were observed in the ash pore water or the Lebanon Limestone groundwater during the investigation of acidic groundwater around the NRS that began in 2015. Ash and limestone can buffer acidic water and appear do so at the NRS.
- Low pH (<5) groundwater in the unconsolidated deposits has primarily been identified around the south perimeter of the NRS.
- Low pH water (<5) is consistently associated with metal concentrations greater than the GWPS, particularly beryllium, cadmium, and nickel. This is evident at wells GAF-441U, GAF-444U, and 19R, and was observed at historical well 6 (now closed), all of which are located around the south and southeastern perimeter of the NRS. As noted in Section 1.1, lithium has also been detected at concentrations above the CCR GWPS at wells GAF-441U, GAF-444U, and 19R, where acidic conditions exist. These wells were all screened in the alluvium. Low pH water enhances the dissolution of the metals from solid material and is understood to be the reason for dissolved metals at concentrations exceeding GWPS at the NRS.
- The concentrations of beryllium, cadmium, nickel, and lithium in the low pH water are higher than concentrations of these metals in NRS ash pore water samples.
- At well GAF-441U, which is located in the inferred source area for acidic groundwater, metals concentrations are highest, and concentrations of several constituents are above GWPSs (see table inset on Figure 2-4). This well is located upgradient of the NRS and is not a compliance well.

2.3 Potential Sources of Low pH and Elevated Metals in Groundwater

Data were collected in the 2015 NRS Phase 1 and 2 investigations to identify potential sources of low pH and elevated beryllium, cadmium, and nickel concentrations in groundwater. It has been documented that pyrite rejects were co-disposed with the ash in the earlier period of NRS operation and that high sulfur coal was used at GAF for many years (TVA 1967). The weathering of pyrite in the presence of oxygen can produce low pH conditions in water, which enhances the dissolution of metals. Leaching of metals can occur both in proximity to the pyritic source of acidic groundwater and in downgradient materials through which acidic groundwater flows. While the acidic groundwater is understood to be caused by pyrite rejects, the elevated metals can originate from soil minerals or coal. Beryllium, cadmium, lithium, and nickel can be adsorbed onto soil minerals or more strongly bound into the structure of minerals making up soil, coal, or coal ash. Under acidic pH conditions, the constituents may desorb or be released due to destabilization of the mineral structure.

An objective of the Phase 2 investigation was to investigate the NRS for the presence of pyritic sulfur to better characterize the nature and extent of source materials for acidic groundwater near the NRS. Approximately 400 soil samples were collected during direct push drilling, and pH was analyzed in the field using the paste pH method. The soil pH was found to be generally lowest (<5) in the alluvial material, becoming more neutral near the alluvium/limestone rock interface. The ash pH was higher than the alluvial material, and typically circumneutral or basic.

Over 100 soil samples with the lowest pH and/or orange-red staining (indicating iron) were analyzed using acid base accounting (ABA). ABA analysis was used to identify and quantify forms of sulfur in soil samples, including sulfate minerals, pyritic sulfur (sulfide minerals), and residual sulfur (i.e., organic sulfur). Pyritic sulfur was detected south of the coal yard runoff ditch in ash, fill, and alluvial materials, primarily in NRS Areas B and D and the southern end of Area C (see Figure 1-3). Most of the soil samples contained pyritic sulfur less than 0.5 percent by weight, although up to 3.7 percent pyritic sulfur was detected in surface soil at boring NRS-036. The higher pyritic sulfur content infrequently coincided with low soil pH (<5) and was not detected in the vicinity of acidic water at wells 19R or GAF-444U or boring NRS-042 (see Figure 2-5).

Five surface water samples were collected from the coal yard runoff ditch during the 2015 Phase 1 and 2 investigations and analyzed for pH. The five samples were within a neutral pH range.

Based on the sampling and analyses of pore water, surface water, and soil during the 2015 Phase 1 and 2 investigations, the CCR within the NRS, the coal yard runoff ditch, the coal pile, and the former Chemical Pond were not identified as potential sources of acidic conditions or elevated metals concentrations in groundwater in wells located at the NRS boundary. The field investigation being performed in support of the field demonstration project, as described in Section 3, will focus on a suspected upgradient source area in the subsurface in the general area of well GAF-441U. This potential upgradient source area is located in the vicinity of the historic ash sluice discharge to the NRS during ash disposal at the site, where heavier pyrites may have more readily settled out of suspension upon discharge to the area. The following observations in this vicinity support the inference of this suspected source area:

- Elevated concentrations of metals and low pH in groundwater at GAF-441U;
- Elevated concentrations of metals at historic wells 6, 10, and 21;
- Low soil pH and pyritic sulfur observed in shallow unconsolidated soil and ash at boring NRS036 and low soil pH in boring NRS035;
- Observations of a mix of coal, ash, and unconsolidated soil in the shallow subsurface;
- Seep 1A, which is located on the slope adjacent to the ash silos and displays orange staining indicative of dissolved ferrous iron that has been oxidized and precipitated as iron oxyhydroxide upon exposure to the atmosphere, and the visual observation of soils and seepage during construction of the Seep 1A collection system in 2013; and
- During recent construction to line the coal yard runoff ditch, dark orange-red seeps formed along an excavated exposure on the north ditch wall just above the bottom of the ditch. This coloration suggests that the water feeding this excavation contained dissolved ferrous iron, which was oxidized and precipitated as orange-red iron oxyhydroxide upon exposure to the atmosphere. These seeps were observed along the ditch generally between wells GAF-441U and GAF-440AR (Figure 2-5). The excavation was backfilled at the completion of construction activities to upgrade the ditch.

2.4 Target Metals Characteristics

While the metals which are the target of the treatability testing have all been mobilized by low pH groundwater, the mechanisms by which metals can be immobilized are dependent upon the specific metal being treated and the geochemistry of the formation. The following sections describe some of the geochemical considerations relevant to treatment of the target metals.

2.4.1 Cadmium

Cadmium (Cd) occurs naturally as CdS (greenockite or hawleyite) or $CdCO_3$ (otavite). Cd more commonly substitutes for zinc (Zn) in minerals such as sphalerite (ZnS), smithsonite ($ZnCO_3$), or zincite (ZnO). Cd concentrations are generally higher in sedimentary rocks than in igneous rocks, and its concentration generally rises with increasing carbon, sulfur, and phosphorus concentrations in rocks (Smolders and Mertens (2013). Naturally occurring Cd is present in soil and coal and is thus present in CCR, as well.

Cd in soils and groundwater is invariably present as Cd^{2+}.The form of Cd encountered depends on solution and soil chemistry, as well as treatment of wastes prior to disposal. Cd hydroxide ($Cd(OH)_2$) and carbonate ($CdCO_3$) solids dominate at high pH, whereas Cd^{2+} and aqueous sulfate species are dominant at lower pH (<8). Under reducing conditions when sulfur is present, the stable solid Cd sulfide (CdS) is formed, and precipitation as CdS controls the mobility of cadmium (Smith et al., 1995).   Cd will precipitate in the presence of phosphate, arsenate, chromate, and other anions, although solubility will vary with pH and other chemical factors.

Cd is more mobile in aquatic environments than most other heavy metals. Cd is largely present as Cd^{2+} up to pH 10 where aqueous $Cd(OH)_2$ ions predominate. In most natural waters, the affinity of Cd for complexing ligands follows the order humic acids > CO_3^{2-} > OH^- ≥ Cl^- ≥ SO_4^{2-} (EPA 1979). Adsorption of Cd by humic substances plays a dominant role in the transport, partitioning, and remobilization of Cd (EPA 1979). Cd concentrations in water are inversely related to pH and the concentration of organics.

Cd is removed from natural waters by precipitation and sorption processes. Soil organic matter, iron (Fe), aluminum (Al), and manganese (Mn) oxyhydroxides, and, to a lesser extent, clay minerals are the three main Cd adsorbents in soil. Cd^{2+} binds to surface oxygen atoms of carboxylic or phenolic groups of humic substances or to surface hydroxyl groups on oxyhydroxides. Cd is bound to organic matter in soils with pH less than 6.5 whereas Fe-Mn-Al oxyhydroxides become more important at pH greater than 6.5 (Smolders and Mertens 2013). Christensen (1984a and 1984b) suggested that sorption, not precipitation, controls Cd at environmentally relevant concentrations. Precipitation is unlikely to control Cd solubility in soil solutions unless at excessive Cd concentrations or at pH values greater than 7. Rao et al. (2010) report that adsorption is commonly used to remove Cd from solution. Adsorbents include Fe-Mn-Al oxides and oxyhydroxides plant waste biosorbents, and phosphate minerals (e.g., apatite).

Cd^{2+} can be precipitated from waters as relatively insoluble carbonate and hydroxide phases at pH values greater than 8 under oxidizing conditions and as an insoluble sulfide under reducing conditions. However, Cd carbonate is relatively soluble below pH 8. Heavy metals are most commonly treated using hydroxide (lime or caustic soda) precipitation because of its low cost and simplicity (Rao et al. 2010). Smolders and Mertens (2013) report that CdS precipitation under sulfate-reducing conditions can render Cd solubility well below 0.1 micrograms per liter (ug/L). Although Cd sulfides (greenockite and hawleyite) exist in nature, it is more likely that mixed Zn-Cd sulfides are formed. Based on Cd hydroxide solubilities, hydroxide precipitation may not successfully reduce Cd concentrations below its GWPS of 0.005 milligrams per liter (mg/L), however, sulfide precipitation is capable of reducing Cd concentrations below its GWPS.

2.4.2 Beryllium

Beryllium (Be) is naturally present in the soil and can also be found in coal and CCR. Be typically exists in groundwater as Be^{2+} (Baes and Mesmer 1976). Be displays similar chemical characteristics to Al due to its similar ratio of charge to ionic radius and is often substituted for Al in natural mineral lattices (e.g., clays). Like Al, Be is least soluble at neutral pH (pH 7.5) and is mobile under acidic conditions. Beryllium salts of chloride ($BeCl_2$), fluoride (BeF_2), nitrate ($Be(NO_3)_2$), phosphate ($Be_3(PO_4)_2$), and sulfate tetrahydrate ($BeSO_4 \bullet 4H_2O$) are all water soluble. However, beryllium oxide (BeO), hydroxide ($Be(OH)_2$), carbonate ($Be_2CO_3(OH)_2$), and sulfate ($BeSO_4$) are either insoluble or sparingly soluble.

Important controls on Be in soils include pH, the amount of organic matter, and the availability of Al, Fe, and Mn hydrous oxides. Be is known to co-precipitate with $Fe(OH)_3$ under alkaline conditions. Taylor et al. (2012) found that Be readily sorbed to various soils and was associated with the exchangeable (27%-37%) and reducible Fe-Mn oxide (42%-62%) soil fractions. Less than 21% of the Be was found associated with the organic and sulfide soil fraction. Be is typically strongly adsorbed in soils to the hydrous oxides, however, soil acidification results in Be release from mineral surfaces or dissolution of metal hydroxides. The lower abundance of Be at high pH is likely due to its removal by co-precipitation with hydrous ferric oxide (Fe(OOH)x, or HFO) or by adsorption on HFO surfaces (Edmunds and Trafford 1992). Where colloidal HFO is low, then significant amounts of Be may be mobile.

In natural waters, Be typically occurs as Be^{2+} and owing to its high charge/ionic radius ratio shows a strong tendency to hydrolyze (EPA 1998). Robertson et al. (2003) report that Be^{2+} is present in groundwaters at pH < 8; whereas at higher pH, the species $Be(OH)_4^{2-}$ dominates. Additionally, other hydroxide species may form, with $Be(OH)^-$, $Be(OH)_2^0$, and $Be(OH)_3^-$ becoming successively dominant from pH 5.5 to 9.6 (Robertson et al 2003). Under alkaline conditions, it may also be stabilized by hydroxycarbonate complexes if pCO_2 is sufficiently high. The presence of F^- is important, as an influence on the mobility of Be in acid waters by the formation of the BeF^+ complex. However, the presence of Al greatly suppresses the formation of Be complexes because Al^{3+}, with its higher valency, complexes with

F^- more readily than Be^{2+} (Edmunds 2011). The most relevant Be species or complexes in NRS groundwater are likely to be Be^{2+} and $BeCO_3$. Be mobility in groundwater is supported by the formation of the BeF^+ or BeF_2 complexes as well as by complexation with humic acids (notably soil fulvic acids above pH 6), but may be suppressed by adsorption, coprecipitation, or ion exchange on natural solids and by the absence of free F^- ions (Edmunds 2011).

Edmunds (2011) reports that soluble beryllium salts present in acidic waters will react to form insoluble hydroxides or hydrated complexes at pH values between 5 and 8 (Edmunds 2011). The solubility of $Be(OH)_2$ decreases from about 7.8 mg/L Be at pH 5 to 0.001 mg/L at pH 9, which suggests that hydroxide precipitation may be an effective mechanism for reducing Be concentrations below its 0.004 mg/L GWPS. Solubility experiments show that amorphous $Be(OH)_2$ can be precipitated from low temperature aqueous solutions and is subsequently transformed to metastable α-$Be(OH)_2$ and then to stable β-$Be(OH)_2$ as the precipitate ages (Lambert and Clever 1992). Bromellite, a BeO mineral, is not known to form at low temperature, although it is shown as stable solid phase over a pH range of approximately 5.5 to 10.5 in The Geochemist's Workbench® modeling package. In groundwater, $Be(OH)_2$ is the most likely stable solid phase.

2.4.3 Nickel

Nickel (Ni) is a natural constituent of soil, with clay soils having higher Ni concentrations than sandy soils. Ni concentrations vary widely depending on local geology and anthropogenic input. Ni also occurs in coal and CCR. Nickel is typically associated with other siderophilic elements, Fe and cobalt (Co), and has a great affinity for sulfur (S). It primarily occurs in nature as Ni sulfide minerals, millerite (NiS), vaesite (NiS_2), and heazlewoodite (Ni_3S_2) or in association with Fe and Co as greigite (Fe_5NiS_8), pentlandite ($(FeNi)_9S_8$, or siegenite ($CoNi_2S$). Although less common, Ni hydroxide, carbonate, sulfate, and phosphate minerals also exist. Intense weathering of ultramafic rocks results in laterites with minable nickeliferous limonite [(Fe,Ni)O(OH)] and garnerite [$(Mg,Ni)_3(OH)_4(Si_2O_5)$].

Like cadmium, the speciation and physicochemical state of nickel is important in considering its behavior in the environment. Nickel has a relatively high affinity for soil organic matter where it complexes with oxygen, nitrogen, and sulfur. Due to its high affinity for organic and inorganic ligands, Ni concentrations in soil solutions are relatively low. Nickel is strongly adsorbed at mineral surfaces such as oxides and hydrous oxides of Fe, Mn, and Al (Evans 1989; Rai et al. 1984). Such adsorption plays an important role in controlling the concentration of nickel in natural waters. Adsorption of nickel onto suspended particles in water is one of the main removal mechanisms of nickel from the water column. The adsorption of nickel on water-borne particulate matter competes with adsorption onto dissolved organic matter, which limits the amount of nickel that can be removed from the water column through the settling of suspended particles (Martino et al. 2003). Much of the nickel released into waterways as runoff is associated with particulate matter; it is transported and settles out in areas of active sedimentation such as the mouth of a river (Bowlby et al. 1988).

The dominant species of nickel found over the pH and Eh ranges of most natural waters is Ni^{2+}. Ni solubility strongly depends on pH, with increased solubility at pH values less than 6, whereas at alkaline pH, Ni may precipitate as carbonates or hydroxides with limited solubility. Under oxidizing conditions, Ni carbonates, hydroxides, and phosphates predominate, whereas sulfate-reducing conditions favor Ni sulfide precipitation. Both hydroxide and sulfide precipitation have the potential to reduce Ni concentrations in groundwater below its 0.1 mg/L GWPS. Solubility data (Lewis 2010; Wilkins and Rogers 2010) indicates that a pH >9 and <13 would be needed to precipitate $Ni(OH)_2$ to reduce Ni concentrations below 0.1 mg/L, whereas NiS could be precipitated across a range of lower pH values typical of groundwater systems. Wilkins and Rogers (2010) found that α-NiS precipitated from sulfidic solutions containing dissolved nickel from 25 to 60^oC. Ni can also be coprecipitated with iron (Fe) sulfides. Studies discussed above suggest that adsorption on HFO, in-situ chemical reduction, or in-situ biogeochemical reduction may be the most reasonable remediation approaches for Ni.

3. Field Investigation

A field investigation will be performed to further develop the CSM with a focus on potential groundwater corrective action, including aspects of the CSM related to the areas where the field demonstration may be performed; to develop data for use in design of the field demonstration; and to obtain samples for use in the treatability testing.

3.1 Field Investigation Objectives

The field investigation has the following objectives:

- To obtain additional information to incorporate into the CSM, including:
    - Locating the source material producing low pH conditions,
    - Assessing the primary groundwater transport pathways between the source area and the downgradient NRS boundary,
    - Estimating groundwater velocity and solute transport time through unconsolidated deposits beneath and around the NRS,
    - Calculating solute flux in field demonstration areas,
    - Assessing the feasibility of various remedial amendment delivery mechanisms (i.e., direct injection, soil mixing, etc.), and
    - Assessing the extent of impacts requiring treatment near the NRS by performing comprehensive sampling of existing wells and focused soil testing;
- To obtain material for the bench-scale treatability study including:
    - Groundwater and native soil representative of the low pH conditions in the alluvium, and
    - Source material potentially responsible for generating the low pH conditions; and
- To provide preliminary design data for the pilot field demonstration, including:
    - Identifying the location and extent of source materials in an area suitable for pilot testing,
    - Characterizing the hydrogeology of potential treatment zones,
    - Delineating the extent of metals impacts within potential field demonstration areas, and
    - Profiling of geochemical characteristics in the potential field demonstration areas.

3.2 Proposed Field Investigation Activities

The following activities are proposed to better develop the CSM for the NRS and to obtain data to be utilized in the field demonstration design.

3.2.1 Groundwater Sampling

Comprehensive groundwater sampling in and around the NRS will be conducted as one of the first tasks in the field investigation. This task will coincide with EIP and/or compliance sampling and is intended to provide a comprehensive dataset describing the distribution of dissolved metals in the unconsolidated deposits. Samples will be collected from 12 existing wells that are screened in alluvium. This sampling event will also include a comprehensive round of groundwater potentiometric surface measurement. After the initial event, up to four additional sampling events may be implemented, based on data from the initial event. The wells to be sampled during this field investigation are identified on Figure 3-1. The list of wells to be sampled may be modified depending on the findings of the ongoing field investigation. Groundwater elevation and ash phreatic surface data will be collected from all wells shown within the NRS footprint, including wells screened in the Lebanon Limestone, and select wells around the perimeter of the NRS.

Figure 3-1 presents the proposed locations of groundwater sampling. Samples will be collected using the methods described in the TDEC-approved sampling and analysis plans (SAPs) associated with the EIP. , Samples for metals analysis will be both field filtered using procedures specified in the relevant SAP and collected as unfiltered samples.

Samples will be analyzed for the parameters listed in Table 3-1. These analytes represent CCR Rule Appendix III, Appendix IV, and Tennessee Rule 040-11-01.04 Appendix 1 Inorganic Constituents. If insufficient sample volume is obtained, the priority will be to analyze for pH, the target compliance metals, sulfate, sulfide and ferrous iron.

Groundwater analysis will be performed in accordance with sampling requirements included in the TDEC-approved Quality Assurance Framework (QAF; Environmental Standards, Inc. [ESI] 2016) and groundwater sampling SAP (AECOM 2016c) associated with the EIP.

Table 3-1 Groundwater Sampling Analytical Summary

Target Metals	Analytical Method*
Beryllium	Analytical lab
Cadmium	Analytical lab
Lithium	Analytical lab
Nickel	Analytical lab
Appendix III Parameters	
Calcium	Analytical lab
Boron	Analytical lab
Chloride	Analytical lab
Fluoride	Analytical lab
pH	Field/Lab instrument
Sulfate	Analytical lab
Total Dissolved Solids	Analytical lab
Appendix IV Parameters	
Antimony	Analytical lab
Arsenic	Analytical lab
Barium	Analytical lab
Chromium	Analytical lab
Cobalt	Analytical lab
Lead	Analytical lab
Mercury	Analytical lab
Molybdenum	Analytical lab
Selenium	Analytical lab
Thallium	Analytical lab
Radium 226 and 228	Analytical Lab
Tennessee-Specific Parameters	
Copper	Analytical lab
Silver	Analytical lab
Vanadium	Analytical lab
Zinc	Analytical lab

Table 3-1 Groundwater Sampling Analytical Summary (cont.)

Other Parameters	Analytical Method*
Dissolved Oxygen	Field instrument
Temperature	Field instrument
Turbidity	Field instrument
Oxidation Reduction Potential	Field instrument
Specific Conductance	Field instrument
Aerated pH	Field instrument**
Acidity, Total	Analytical lab
Alkalinity, Total as $CaCO_3$	Analytical lab
Alkalinity, Hydroxide as $CaCO_3$	Analytical lab
Alkalinity, Bicarbonate as $CaCO_3$	Analytical lab
Alkalinity, Carbonate as $CaCO_3$	Analytical lab
Dissolved Carbon Dioxide	Colorimetric field test kit**
Aluminum	Analytical lab
Iron	Analytical lab
Manganese	Analytical lab
Nitrate-Nitrite	Analytical lab
Total Kjeldahl Nitrogen	Analytical lab
Ferrous Iron [Fe(II)]	Colorimetric field test kit**
Magnesium	Analytical lab
Phosphate	Analytical lab
Potassium	Analytical lab
Sodium	Analytical lab
Sulfide	Colorimetric field test kit** / Analytical lab
Total Organic Carbon	Analytical lab
Total Suspended Solids	Analytical lab

* Specific analytical methods are identified in the QAF and SAPs.

** Specified analytical methods are discussed in the SAP provided in Appendix B.

3.2.2 Soil Borings

Limited subsurface investigation will be conducted in the suspected source area for the low pH and elevated metals in groundwater. The area of interest is in the general vicinity of well GAF-441U, boring NRS-035, the ash silos, and the coal pile. Initially, seven soil borings will be advanced to bedrock to identify indications of potential source material in the suspected source area at the approximate locations depicted on Figure 3-1. Up to five additional boring locations will be completed in this area, at locations to be determined based on the results obtained from the initial borings. The final locations of the soil borings in the suspected source area will be determined based on accessibility considerations and observations from prior borings.

Soil samples from these borings will be observed for the presence of pyrite source material. At each soil boring, up to six (6) soil samples will be collected for ABA testing, using the methods employed during the Phase II investigation of the NRS (AECOM 2016a). Details of the ABA testing are provided in the SAP provided in Appendix B.

When shallow groundwater is encountered in soil borings, pH, DO and, if practical, ORP will be measured in the field, and, where the boring produces sufficient yield, a groundwater sample will be collected for analysis of the dissolved target metals identified in Table 3-1. Because the purpose is to understand the geochemical conditions of the groundwater, samples will be field filtered to remove suspended particles that are expected to be present in an open boring.

The three soil borings proposed near wells GAF-444U and 19R (Figure 3-1) will be drilled primarily to collect soil material for the bench-scale treatability test, as discussed in Section 3.3.2.

The investigation tools for these areas may include direct-push technology, hollow-stem auger, or sonic drilling. Rigs capable of performing direct-push or hollow-stem auger drilling will be used for the initial mobilization. If difficult drilling conditions are encountered, a sonic drill rig may be mobilized to complete the investigation. Sonic drilling methods were detailed in the hydrogeologic characterization SAP (AECOM 2016b) previously approved by TDEC.

3.2.3 Hydraulic Conductivity Testing

In-situ hydraulic conductivity (slug) testing will be performed at four wells not previously tested at the NRS (i.e., wells GAF-440U, GAF-442U, GAF-444U, and GAF-489U), which are screened in the alluvium to update the conceptual model and develop the field demonstration design. The wells to be slug tested are shown on Figure 3-1. Testing will be performed using rising or falling-head (slug) tests. It is anticipated that slug test data will be analyzed using the Bouwer and Rice (1976) method, and the results will be analyzed to derive hydraulic conductivity values for alluvial materials. If sufficient permeability is identified in any wells, a short-term aquifer pumping test may be conducted to further assess hydraulic conductivity. Where testing indicates lower permeability, drawdown monitoring data from low-flow groundwater sampling will be used to provide an independent check of hydraulic conductivity testing results. Data from low-flow sampling will be analyzed using the method of Robbins et al. (2008). Procedures for slug testing were detailed in the TDEC-approved hydrogeologic characterization SAP associated with the EIP (AECOM 2016b).

3.2.4 Groundwater Profiling

Up to six borings will be advanced to the top of bedrock along the perimeter dike near well GAF-444U for the purpose of groundwater sample collection. This area, along with the well 19R area, are currently considered the most promising areas for performing the field demonstration, and groundwater profiling has already been performed in the 19R area. The locations where the groundwater profiling will be performed are depicted on Figure 3-1. The specific locations may be adjusted based on accessibility considerations, a review of bedrock surface elevation contours, and observations from prior borings.

Groundwater profile sampling involves the advancement of drilling rods and the periodic collection of groundwater samples through a retractable sampler. The sampler screen interval is typically much shorter (e.g., 12 to 24-inches) than a well screen and can provide data representative of discrete layers in the subsurface. Groundwater profiling will be performed in conjunction with the use of a Hydraulic Profiling Tool (HPT) to characterize the relative permeability of subsurface deposits. These data will be used to select screen intervals for monitoring well installation.

Where the boring produces sufficient yield, pH, DO, and ORP will be measured in the field, and up to three groundwater samples per boring will be collected for analysis of the dissolved target metals identified in Table 3-1. Because the purpose is to understand the geochemical conditions of the groundwater, samples will be field filtered to remove suspended particles that are expected to be present in the active boring. Groundwater sampling from active soil borings is detailed in the SAP provided in Appendix B.

3.2.5 Monitoring Well Installation

Based on the results of soil and groundwater sampling described in Section 3.2.2 and groundwater profiling described in Section 3.2.4, up to six monitoring wells may be installed in the suspected source area or in the vicinity of well GAF-444U. The locations of the wells and depths of the well screens will be selected to be representative of the subsurface areas where low pH is present. These wells will be developed, and groundwater samples will be collected from them for analysis of the parameters identified in Table 3-1. The wells may also be used for collection of groundwater for treatability testing.

3.3 Treatability Test Sample Collection

The interaction of remedial amendment, groundwater, and soil matrix is an important component of the treatability testing. The alluvial material in the vicinity of well 19R and GAF-444U will be targeted for collection, as will source area subsurface materials (in vicinity of well 441U) identified during the soil boring investigation described in Section 3.2.2.

3.3.1 Groundwater Collection

Groundwater samples for treatability testing will be collected at wells displaying acidic groundwater in the vicinity of wells 19R, GAF-441U, and GAF-444U. Treatability testing is anticipated to require approximately 20 gallons of water from each well over the course of the program. Groundwater will be periodically collected for treatability testing as the testing program proceeds to reduce the amount of time each batch of groundwater is stored in the laboratory.

Groundwater will be purged from wells using the sampling techniques referenced in Section 3.2.1. Following purging, unfiltered groundwater will be placed in suitable containers. The containers will be filled with minimal headspace to help preserve the reduction/oxidation (redox) state of the groundwater and will be stored on ice for transport to the treatability laboratory.

3.3.2 Soil Sampling

Soil samples from the presumed source areas around GAF-441U and from the downgradient areas around wells GAF-444U and 19R will be collected from a series of co-located borings. Locations of the borings are depicted in Figure 3-1. Borings will be advanced using direct push, sonic drilling, or hollow stem auger techniques. A subset of samples will be collected by Shelby tube, where appropriate, to reduce disturbance of samples, compared to other methods of soil sample collection, and thereby obtain samples that better approximate the structure and redox conditions in the source material and likely treatment areas. The Shelby tubes will be sealed to better maintain the natural soil redox state. Methods for Shelby tube sampling were provided in the TDEC-approved SAP [for] Overburden Soil Borings, Native Soil Characterization, and Seep Sampling associated with the EIP (AECOM 2016d).

Collection of approximately 10 gallons of saturated soil from each area is anticipated. Samples will be collected from intervals known to exhibit source material or low pH groundwater in the presence of alluvial material (e.g., the screen interval of well 19R), and therefore, multiple co-located borings may be required to complete sample collection. The soil samples will be stored on ice for transport to the treatability laboratory.

Representative soil samples from each type of sampling location (e.g., alluvial clay, source area materials) will be collected for analysis of the parameters listed in Table 3-2. These data will be obtained to better understand the minerology of the soil being used in the treatability test.

3.3.1 Quality Control

Soil samples for the treatability test will be collected using techniques that limit disturbance of the sample and contact with air. Direct push sample cores will be retrieved in plastic liners and will be immediately capped and taped. Sonic cores will be extruded into plastic bags, sealed, and packed to minimize potential disturbance. Shelby tubes will be sealed within the sampler with wax upon collection. Groundwater samples will likewise be collected and stored using methods that minimize headspace in the container and the introduction of air into the sample, so as to minimize disturbance of the redox state of the sample.

The analyses performed in support of the field investigation will be conducted using a combination of direct-read instrumentation, colorimetric test kits, and laboratory analyses. Samples for which the primary source of potential error is related to geochemical changes in samples due to holding times (e.g., pH, ORP, ferrous iron, sulfide) will be performed in the field, and analyses requiring specialized analytical instrumentation will be performed by Eurofins Test America, using the procedures described in the TDEC-approved GAF SAPs and QAF documents. A SAP is provided in Appendix B to detail methods not documented in a previously approved SAP.

Table 3-2 Treatability Test Soil Sampling Analytical Summary

Target Metals	Analytical Method*
Beryllium	Analytical lab
Cadmium	Analytical lab
Lithium	Analytical lab
Nickel	Analytical lab
Other Metals and Metalloids	
Aluminum	Analytical lab
Antimony	Analytical lab
Arsenic	Analytical lab
Barium	Analytical lab
Boron	Analytical lab
Calcium	Analytical lab
Chromium	Analytical lab
Cobalt	Analytical lab
Copper	Analytical lab
Iron	Analytical lab
Lead	Analytical lab
Magnesium	Analytical lab
Manganese	Analytical lab
Mercury	Analytical lab
Molybdenum	Analytical lab
Phosphorous	Analytical lab
Potassium	Analytical lab
Selenium	Analytical lab
Silver	Analytical lab
Sodium	Analytical lab
Sulfur	Analytical lab
Thallium	Analytical lab
Vanadium	Analytical lab
Zinc	Analytical lab
Other Parameters	
pH	Field/lab instrument**
Total Inorganic Carbon	Analytical lab**
Total Organic Carbon	Analytical lab
Other Analyses	
Acid-Base Accounting***	Analytical lab**
Sequential Extraction****	Analytical lab**
X-Ray Diffraction	Analytical lab**

* Specific analytical methods are identified in the QAF and SAPs.

** Specified analytical methods are discussed in the SAP provided in Appendix B.

*** Includes total sulfur, sulfate, pyritic sulfur, residual sulfur, acid neutralization potential, and net acid neutralization potential.

**** Sequential extraction will analyze for beryllium, cadmium, lithium, nickel, and iron.

3.4 Ash Management Plan

Ash is not expected to be encountered for drilling activities proposed in the vicinity of 19R or GAF-444U. However, based on previous drilling observations, a mix of coal, ash, and soil may be encountered in the vicinity of GAF-441U. Up to 12 borings are planned in the potential source area near well GAF-441U, the coal yard, and the coal yard runoff ditch. Initially seven borings will be drilled in this area, as shown in Figure 3-1**.** Based on the results of the initial seven borings, up to five additional borings will be drilled in the same area (exact locations to be determined during the investigation).

Sonic, hollow-stem auger, or direct push drilling methods are planned to advance the borings and collect samples. The borings will be advanced through fill, ash, and native soil, and terminated at the top of bedrock. The proposed borings are summarized below:

- Up to 12 boring locations ranging from 25 to 75 feet in depth, with an average depth of 45 feet;
- Total estimated footage 540 feet;
- Assuming that the borings are drilled with a sonic drilling rig with 6-inch outer casing, approximately 9 cubic feet of material will be collected at each boring. The total volume is estimated to be 108 cubic feet (4 cubic yards).

The total quantity of CCR to be encountered is unknown at this time but is anticipated to be less than 1 cubic yard. A portion of this material will be placed in sealed containers and transported for laboratory testing as part of the treatability testing. Any excess ash or soil remaining that is not containerized and transported for laboratory testing will be placed back into the open boring as part of their abandonment. Excess soil may also be spread at the ground surface.

If any additional activities are identified in the field, TDEC will be notified prior to those activities.

4. Treatability Testing

The following sections describe the laboratory treatability testing activities that will be performed to evaluate potentially applicable remedial amendments and develop design criteria for their use in the field demonstration.

4.1 Objectives of Treatability Testing

The primary objective of the treatability testing is to identify at least one reagent that has the potential to do the following:

- Be delivered *in situ,*
- Alter local geochemistry such that dissolved metals are sequestered by precipitation or sorption,
- Provide sustained treatment capacity in the native formation,
- Achieve GWPS for metals in groundwater, and
- Minimize mobilization of non-target metals.

Secondary objectives of the treatability testing are, in conjunction with the field investigation, to develop design parameters (e.g., dosing rates, barrier composition and thickness) necessary to design the field demonstration and, in conjunction with the field demonstration, to develop information necessary to perform a feasibility evaluation for the NRS CARA Plan (e.g., estimates of treatment longevity and operations and maintenance requirements).

4.1.1 Treatability Test Performance Standards

The specific performance standards for the treatability test include identifying a reagent that:

- Is appropriate for safe handling and application at field scale at the NRS in the vicinity of the Cumberland River,
- Reduces metals concentration to below GWPS in groundwater,
- Sequesters metals such that they are not remobilized at concentrations above GWPS,
- Does not alter geochemistry in such a way as to mobilize non-target metals at concentrations above the GWPS, and
- Has the potential to be utilized in a long-term cost-effective remedial treatment in terms of capital cost and operations and maintenance.

4.1.2 Treatability Test Interim Benchmarks

The treatability test is the first step in the larger field demonstration project, and the interim benchmark associated with the treatability test phase of the Order implementation is the submittal of the treatability testing report, which is described in Section 6. The schedule for this interim benchmark and subsequent activities associated with the field demonstration project are provided in Section 7.

4.2 Conceptual Description of Treatment of Metals

The fate and transport of a metal in soil and groundwater depends significantly on the chemical form and speciation of the metal (Allen et al., 1991). The physical and chemical form of the metal in soil or water strongly influences the selection of the appropriate remediation treatment approach. Information about the physical characteristics of the site and the type and concentrations of metals at the site must be obtained to enable accurate assessment of site conditions and remedial alternatives. The mobility of metals in groundwater systems is hindered by reactions that cause metals to adsorb or precipitate, or chemistry that tends to keep most metals associated with the solid phase and prevent them from dissolving. These mechanisms can inhibit the movement of metals (NRC 1994).

A variety of methods are available for immobilization of metals, including those that use chemical reagents to physically bind the source materials in soil. Immobilization technologies are designed to reduce the mobility of metals by changing the physical or leaching characteristics of the contaminated matrix. Mobility can be decreased by physically restricting contact between the metals and the surrounding groundwater, or by chemically altering the metals to make it more stable with respect to dissolution in groundwater. Some of the potential mechanisms for treatment of target methods were described in Section 2.4.

4.3 Selection of Reagents for Testing

A bench study was completed between 2017 and 2019 as a preliminary test to demonstrate removal of Be, Cd, and Ni from groundwater samples to meet applicable standards and to provide a decision-basis for the development of additional pre-design studies. The amendments used in the bench study test included sodium hydroxide (NaOH), EnviroBlend (EB), AQUAMAG, , which promote precipitation of hydroxides and oxy-hydroxides of iron, aluminum, and manganese, to which beryllium, cadmium, and nickel may sorb, and zero-valent iron (ZVI) and FerroBlack-H (FB-H) that alter pH and/or oxidation-reduction potential (ORP) and promote metal sulfide precipitation. The results of the study indicated that successful treatment of the target metals was achieved in the NaOH and EB treatments, and partial success of one or more metals was achieved with ZVI and FB-H. Successful treatment was not achieved with the AQUAMAG sample.

Removal or precipitation of metals in a laboratory setting is straightforward and many different reagents could be effective. However, in a remediation site setting, it is important to identify and consider site-specific factors. Evaluation criteria specific to the NRS are shown in Table 4-1.

Table 4-1 Reagent Evaluation Considerations

Criteria	Evaluation Considerations
Safety	The material must be safe to handle by remediation workers, must not generate toxic or explosive gases, and must be compatible with pH of groundwater at the site.
Effectiveness	Precipitate and immobilize soluble metals in groundwater and soil. Ability to provide long-term treatment is also required.
Avoiding Adverse Impacts to Surface Water and Downgradient Areas	The reagent must not cause other metals or contaminants to be mobilized in groundwater or to impact surface water. The reagent must not result in parameters exceeding surface water criteria and must not cause visible discoloration.
Ease of *in situ* injection	At this time the method of applying the reagent has not been determined. Some reagents are more soluble or have other properties that would make injection easier.
Proven Technology	Reagents that have been used successfully on other similar projects are preferred over reagents that have not previously been used for metals treatment.

Safety data sheets for reagents under consideration for bench scale testing are provided in Appendix C. Table 4-2 provides the results of screening a variety of reagents, based on the above criteria and consideration of the prior bench-scale testing results.

Table 4-2 Screening of Reagents

Reagent	Safety	Effectiveness	Adverse Impacts to Streams or Downgradient Areas	Proven Technology	Ease of In Situ Injection	Retain?
NaOH (lye)	Corrosive, strong base	Worked well in previous titration test. Limited long-term effectiveness is a concern.	None identified	Yes, has been used for pH adjustment for in-situ use.	Easy to inject	Yes
Potassium hydroxide (KOH)	Corrosive, strong base	Expected to be effective for pH adjustment	None identified	Yes, has been used for pH adjustment for in-situ use.	Easy to inject	Yes
FerroBlack®-H (FeS/NaHS)	H_2S generation at low pH a concern. Evaluate during bench test.	Previous titration test results mixed.	Mobile fraction (NaHS) could impact surface water. pH may be elevated. Evaluate during bench test. Possible other metals in FB-H.	Very effective for As, Ni, Cd, Be, Pb and other multivalent metals	Suspension of iron particles, difficult to uniformly distribution. Has been successfully injected at some sites.	Maybe – will discuss customizing blend for this site with supplier
EnviroBlend® (Magnesium oxide [MgO]/hydroxide [MgOH] product)	No major issues	Worked well in previous titration test. Alkaline reagent with high buffering capacity	None identified	Yes, primarily used *ex situ* for soil treatment but has also been used *in situ*.	Powder or pellet form can be mixed with water for simple injection.	Yes
Nano-scale ZVI	No major issues, must control dust	Micro-scale ZVI tested previously in titration test. Effective for Cd & Be, but limited effectiveness for Ni.	Mobility in the environment and toxicity is a controversial issue.	Proven technology for hexavalent chromium (Cr VI) treatment. Lowers ORP to promote precipitation of some metals.	Moderately difficult, but easier to inject than micro-scale ZVI due to smaller particle size.	No
Micro-scale ZVI	No major issues, must control dust	Mixed results in previous titration test.	High mobility potential to impact the river.	Proven technology for soil mixing in reactive barriers and source areas.	Difficult to get good distribution with slurry injection.	Maybe
Metals Remediation Compound (MRC) - organosulfur ester/polylactate	No major issues	Effectiveness unknown. Could provide short-term treatment and long-term bio treatment by changing redox conditions.	May potentially enhance mobility of other metals	Yes	Moderately difficult to inject and obtain uniform distribution.	Maybe

Reagent	Safety	Effectiveness	Adverse Impacts to Streams or Downgradient Areas	Proven Technology	Ease of In Situ Injection	Retain?
Calcium Polysulfide (CaS_x)	High pH, potential to generate H_2S in contact with acids. Combustible.	Unknown; treatment relies on native iron; may not be as effective as FerroBlack.	Highly mobile and deep red color, may impact surface water.	Proven technology for Cr VI.	Highly mobile, easy to inject. Plugging of wells with $CaSO_4$ possible.	No
Crushed limestone/ dolomite – $CaMg(CO_3)$	No safety issues	Uncertain, weak alkaline reagent with good buffering capacity	None anticipated	Limestone commonly used for pH adjustment	Not possible to inject, but could be soil mixed	Yes
AQUAMAG (blended phosphates)	No safety issues	Not effective in titration test.	None anticipated	Proven for lead and copper. Limited data for Cd.	Easy to inject.	No
$CaO/CaCO_3$ (lime)	No safety issues	Uncertain, weak alkaline reagent with good buffering capacity	None anticipated	Proven for pH adjustment.	Easy to inject. $CaSO_4$ plugging of wells possible.	Yes
Sodium carbonate/ bicarbonate ($Na_2CO_3/NaHCO_3$) - baking soda	No safety issues	Uncertain, weak alkaline reagent with good buffering capacity	None anticipated	Used widely for various purposes but use for treatment of metals in groundwater limited.	Highly mobile, easy to inject.	Yes
Potassium bicarbonate ($KHCO_3$)	No safety issues	Uncertain, weak alkaline reagent with good buffering capacity	None anticipated	Use for treatment of metals in groundwater limited.	Highly mobile, easy to inject. Plugging of wells possible	Yes (or pick either $NaHCO_3$ or $KHCO_3$)
Apatite ($(Ca_5PO_4)_3(F,CL,OH)$)	No safety issues	Uncertain, effectiveness depends on site conditions	None anticipated	Excellent buffer for neutralizing acidity through PO_4^{-3}	Granular, powder, or slurry. Can be injected; not likely to be highly mobile.	Yes
Zeolite (aluminosilicates of Na, Ca, K, Mg, or Ba)	No safety issues	Uncertain, effectiveness depends on site conditions	Could introduce other metals	High selectivity for many metals	Moderately difficult to inject and obtain uniform distribution.	Maybe
Emulsified vegetable oil (EVO)	No safety issues	Unknown, could form soluble organo-metals complexes	None anticipated	As biological amendment for treatment of Cr IV. Otherwise not demonstrated.	Easy to inject but wells can become fouled.	No

Reagent	Safety	Effectiveness	Adverse Impacts to Streams or Downgradient Areas	Proven Technology	Ease of In Situ Injection	Retain?
Provect-IRM (micro-scale ZVI, activated carbon, KaMgSO4, guar, yeast extract)	No safety issues	Uncertain, contains a combination of reagents and treatment mechanisms	None anticipated	Commercial product, not proven for this mix of metals.	Moderately difficult to inject. Powder or granular. Possible to inject as slurry.	Yes, will discuss customizing formulation with vendor, maybe remove guar
PeroxyChem GeoForm Soluble (sulfate,ferreous iron.emulsified organic carbon)	No safety issues	Unknown	Organic carbon could lead to formation of organometal complexes	Commercial product, not proven for this mix of metals	Should be relatively easy to inject. Soluble solution designed for injection.	No, similar to Ferroblack-H and Provect-IRM, but more likely to create organometals
PeroxyChem GeoForm Extended Release (organic carbon, sulfate, ferrous iron, micro-scale ZVI)	No safety issues	Unknown	Organometal complex formation a slight concern, mobility of product is low	Commercial product, not proven for this mix of metals	Not designed for injection, designed for PRB wall	Yes, may adjust formulation after discussion with vendor

4.4 Treatability Testing Approach

This section describes the specifics of obtaining test samples, test set-up and equipment, and testing procedures. Testing will consist of titration testing using remedial amendments with just groundwater and microcosm (bucket) testing with both soil and groundwater, followed by column testing. An idealized flow chart for the process of treatability testing is provided as Figure 4-1. The testing steps depicted in this schematic are intended to be progressively more rigorous with the list of reagents reduced during each subsequent step in the process, such that the most complicated and rigorous testing is done on the reagents that show the most promise for field application, based on the prior simpler steps. The screening step presented on this graphic is summarized in Table 4-3.

Simple titration testing with site groundwater will be conducted first to confirm that adjustment of pH and precipitation of metals can be performed and to provide an initial estimate of appropriate dosing. Following the titration testing, microcosm testing that utilizes both groundwater and soil from the site will be conducted to observe the interaction between the reagent in the presence of a soil matrix. Lastly, several forms of column testing will then be performed to simulate the flow of site groundwater through soil where a remedial amendment has been applied.

4.4.1 Analytical Approach for Treatability Testing

While the nature and duration of the treatability bench tests performed become more complex as the reagent list is reduced, the analytical component of the testing likewise becomes more complex. The analytical strategy is to limit testing to the basic performance criteria (i.e., pH, redox indicator parameters, and target metals) in the initial, simpler bench-scale tests. The analytical tests and approximate numbers of samples for each step of testing are summarized in Table 4-3.

The analyses presented in Table 4-3 are a guideline. Flexibility will be retained in the analytical program, such that as data is obtained from the treatability testing, elements of the analytical suite may be added, omitted, or increased or decreased in frequency. For example, additional analyses may be introduced to target key components or potential impurities in specific treatment reagents. The need for modifying the testing program is likely to increase as the treatability testing progresses to evaluating a smaller list of promising reagents.

4.4.2 Facilities and Equipment for Treatability Testing

The bulk of the treatability testing will primarily be performed at a treatability testing laboratory unaffiliated with potential remedial amendment vendors. However, limited testing may initially be done by the reagent vendors. Any testing by vendors will later be verified by testing at an independent laboratory.

For testing, the following facilities are required:

- A secure laboratory space where chemicals can be stored and glassware cleaned;
- Laboratory bench space, glassware, magnetic stirring plates, and a fume hood;
- A temperature-controlled laboratory space that can maintain temperatures of 50 to 75°F;
- A spill kit, readily available;
- Chemical storage cabinets (for raw chemicals, samples, and investigation-derived waste) that allow separate storage of incompatible chemicals (e.g., strong acids and bases);
- A refrigerator for storage of test samples;
- Test buckets that can be vented to the outside, and.
- Storage space for up to two 55-gallon drums of investigation derived waste.

4.4.3 Titration Testing

Titration testing involves the addition of measured amounts of a remedial amendment to a container of groundwater to determine the amount of the amendment necessary to sequester metals from solution in the groundwater. Titration testing will be used to provide some early indication of the effects of treatment on pH, ORP, and target metals concentrations; the potential for H_2S generation; and the dose required to amend pH. The titration testing would only require one or two days to complete per test. Depending on laboratory results, a second round of titration tests may be conducted (e.g., using a different amendment dose or groundwater from another part of the site). In these tests, reduction in metals concentrations should be apparent if the reagent is going to be effective.

Several trials may be conducted, depending upon observations during the initial testing. The previous bench tests used doses of 10 g/L for solid amendments and 2.6 mL/L for 25% weight for the aqueous solutions. This will serve as the baseline for this treatability test, but varying amendment doses may be tested.

4.4.4 Microcosm Testing – Groundwater and Saturated Soil

In the microcosm (bucket) tests, soil will be blended with test reagents and then dosed with impacted site groundwater. The reagents for microcosm testing will be selected based on the results of the titration tests. The microcosm tests are designed to simulate the interactions of site groundwater, test reagents, and soils. Testing will be performed using both site soils and clean sand. The clean sand will be used to evaluate the chemistry effects within a hypothetical permeable reactive barrier (PRB). The site soil used for testing will be collected from impacted portions of the site, as described in Section 3.3. The sand used to simulate chemistry within a PRB will be a poorly-sorted medium sand with low organic content (i.e., concrete sand).

The equipment for each of the microcosm tests includes a plastic bucket with an air-tight lid, a tap-style spigot and gasket, and a vent line with an activated carbon filter. The microcosm testing typically requires one or two days to prepare the test vessels. Then, the test vessels are left to react for two weeks. For biological reagents, the reaction time may be extended to several weeks. During the reaction period, the test vessel must be vented to the outside and maintained within the temperature range of the site subsurface. During the reaction period, minimal attention to the vessels is required; periodic inspections (every other day) to confirm the vessels are undisturbed is desirable.

In the first series of tests, the treatment reagent is blended with site soil from the anticipated treatment interval and placed in the test vessel. During each series of tests, a control bucket will be prepared, consisting of site soil and groundwater but no reagent. Site groundwater is then added to the test vessel. The first of three rounds of sampling is performed after allowing one week for the reagent to react with site groundwater and soil. If metals concentrations are reduced to below treatment goals in a test bucket, the water will be drained from the bucket using the spigot and the bucket will be re-filled with impacted groundwater. The reaction will be allowed to proceed for another week, and the water will be re-tested in the same manner as before. If metals concentrations are not reduced to below treatment goals, the water will be left in the bucket, and re-sampling will be performed after another week with the same water in place. If concentrations are not showing signs of reduction following the second week, the test may be discontinued, except for amendments which rely on biogeochemical processes to effect treatment, which are typically continued for longer durations and tested less frequently.

The testing may be extended or modified as results are obtained. The reagents with the best performance will be subjected to further testing. Further testing typically includes draining the test vessel and applying more doses of impacted groundwater until breakthrough occurs (i.e., target metals exceed or approach treatment goals).

During microcosm water sampling, water is drawn out of the bottom of the test vessel through a dedicated spigot. Approximately four ounces of water will be drained from the spigot prior to sampling. Sampling parameters are indicated in Table 4-3. Color and presence of solids in the water will be noted, and the water will be tested for pH, dissolved oxygen, and ORP. Samples will be submitted to Eurofins Test America for expedited analysis.

Following completion of the final round of water testing, soil sampling will be performed on the buckets showing the best results and the control bucket. The bucket will be drained of water and the top removed. Soil will be collected from the bottom third of the bucket. Laboratory analysis for soil will include total metals and pH. Soil will be mixed 50% with deionized water to measure pH.) Table 4-3 specifies sample numbers and analyses during microcosm testing but is subject to change based on reagents selected for the microcosm tests based on the results of titration testing.

4.4.5 Column Testing

To test the proof-of-concept of the *in-situ* remediation process, flow-through column tests are performed. The tests are designed to evaluate how long the reagents are likely to last in the subsurface and how site-specific conditions, including groundwater flowing through amended soil would affect metals removal by a remedial amendment. For example, precipitation of metals might clog the system and cause a preferential flow path to develop that reduces treatment efficiency. Column tests also allow simulation of processes that occur over time in groundwater systems, such as desorption of immobilized metals as groundwater flows through a treatment media that has been removing dissolved metals from groundwater.

Two types of column tests will be conducted:

- Columns filled with site soil blended with test reagents; and
- Columns filled with permeable media (e.g., medium sand with minimal organic carbon) test blended with reagents.

For each of the above types of test, a control column (i.e., site soil with no reagent and clean sand with no reagent) will be tested.

The columns will be constructed of an acrylic, polypropylene, or PVC tube and will be used to simulate one-dimensional flow through *in-situ* treatment zones by passing groundwater through columns containing soil. The column dimensions will be determined based on the hydrogeological conditions at the site, the target flowrate, and the sample volumes to be collected. These test design parameters will be determined based on data from the field investigation described in Section 3.0. Samples will be collected with ports at the column influent, effluent, and in some cases, one or more sampling points along the columns. Site groundwater is pumped through the columns from the bottom using a peristaltic pump to perform an up-flow column test, which will limit the potential for geochemical changes that can occur in down-flow tests. Control experiments without remedial amendments will be conducted using the same groundwater and solid media to evaluate target metal behavior if no reagents added. The experimental design is presented in Table 4-4.

Table 4-4 Column Test Design

Column Type	Test Description	Soil	Amendments
Control	Soil only	X	
Test 1	Soil with amendment 1	X	X
Test 1	Soil with amendment 2	X	X
Test 1	Soil with amendment 3	X	X
Control PRB	Clean Sand Only		
Test 2 PRB	Sand with amendment 1		X
Test 2 PRB	Sand with amendment 2		X
Test 2 PRB	Sand with amendment 3		X

Samples will be taken from the column influent, one or more sampling points along the columns, and the effluent of the column. Between 8 and 10 samples for the mid-point and effluent are recommended in order to increase the probability of characterizing breakthrough for the three target metals. The metals analyses will be performed by Eurofins Test America, in accordance with the QAF (ESI 2016) and approved SAP for groundwater sampling (AECOM 2016c), while parameters such as pH, ORP, DO, specific conductivity, sulfide, and ferrous/ferric iron will be monitored by the treatability testing laboratory.

To test the reagents within a simulated PRB, the reagents are blended with a relatively permeable and inert material (e.g., concrete sand, which is poorly sorted medium sand with low organic carbon content) and placed in a flow-through column as described above. A similar experimental design and sampling schedule described for the native soil columns are used for the amended sand columns. Column testing of the simulated PRB includes observing the reagent/sand mixture for signs of plugging. Additional testing to evaluate changes in pressure required to push water through the reagent/sand mixture may be conducted if there is evidence of plugging.

The breakthrough curves among the amended columns will be compared to determine which media recipe is likely to have the highest longevity. Following completion of the column tests, the soil from the columns with the remedial amendments showing the most promise for field application will be sampled for laboratory analysis. The soil will be shipped to Eurofins Test America for testing of target metals and other species identified in Table 4-3 and 3-1. The soil will also be subjected to a sequential extraction analytical process, whereby the nature of the metals immobilized within the column can be determine via a series of progressively more aggressive extractions.

The sequential extraction process is used to quantify the fractions of metals that exist in various forms within column soils. The forms that are sequentially extracted by this analytical procedure (in general order of increasing durability and anticipated stability in the environment), are as follows:

- The exchangeable phase, which are metals sorbed by electrostatic forces;
- The carbonate phase, which are metals bound or sorbed to carbonate minerals;
- The non-crystalline materials phase, which are metals complexed by amorphous solids;
- The metal hydroxide phase, which are metals bound to oxides and hydroxides of iron, manganese, or aluminum;
- The organic phase, which are metals bound by chemisorption to organic material;
- The acid/sulfide fraction, which are metals associated with sulfide minerals; and
- The residual fraction, which include metals incorporated into the mineral structure of the soil.

This analysis will help identify the mechanism of removal of metals from solution, which will help assess the likely longevity of a given treatment and provide information that can be used in the design of the field demonstration or additional treatability tests, as necessary.

Additional mineral analysis by x-ray diffraction and x-ray fluorescence may also be performed, depending on the results of the treatability testing.

Depending on the results of the column testing (e.g., if flow rates through native soil mixtures are too slow), additional column tests (e.g., triaxial tests) utilizing pressurized systems may be performed to produce higher flow rates and thereby evaluate the potential long-term behavior of remedial amendments. Such tests would be run to determine breakthrough, following exhausting the treatment capacity of an amended column, and thereby estimate longevity of treatment in the field.

4.5 Evaluation and Use of Data

Bucket testing results will be compared to the control sample (backfill with no amendments). If concentrations of total and dissolved metals in pore water are significantly reduced (e.g., by 90% or such that treatment goals are achieved), then the treatment will be considered viable. Increases in solubility of other metals compared to the control will also be considered in evaluating the viability of each remedial amendment. Each amendment type will be evaluated against the five criteria listed in Section 4.1. Based on the results, a specific optimal formulation may be apparent or appropriate adjustments in the formulation obvious. Based on results from these bucket tests it may be recommended to perform additional tests to further refine the formulation.

Maintaining flexibility and adapting during the treatability testing process is critical to success. As testing proceeds, changes in test set-up and analytical testing are likely, as the behavior of individual amendments during the tests is assessed.

Data will be evaluated and prioritized as follows:

1. The amendment must show the ability to meet the treatment goals for the target metals (Be, Cd, and Ni). Amendments failing this criterion will be dropped from further consideration. Testing for Cd, Be, and Ni are the key parameters in the early testing.
2. The amendment must not create adverse effects (e.g., mobilizing other metals at concentrations exceeding GWPS). In this case, modifications will be considered to counteract the adverse effects. Later tests include a broad list of metals.
3. The required dose of the amendment determined by treatability testing must be one that can be effectively delivered at a field scale.
4. The amendment must be durable when applied to site conditions or be readily replenished. A series of tests are planned to understand the composition of the precipitates and effects on overall water chemistry. An understanding of the resulting soil and water chemistry is key to evaluating durability of the treatment. This series of tests is the most expensive and will be conducted only on the most successful reagents.

The above data will be integrated with the expanded understanding of potential treatment area hydrogeology and geochemistry obtained during the field investigation to develop recommendations and design parameters for the field demonstration.

4.6 In Situ Stabilization Testing

In-situ stabilization (ISS) is designed to both fix the metals within a matrix and to create a low permeability zone that minimizes groundwater flow through the treated area and reduce the mass flux of metals from the stabilized soil. ISS could be applied to the source area or groundwater plume area. The base or primary reagent for ISS is typically Portland cement. Other reagent such as blast furnace slag or bentonite are sometimes added to improve specific properties (strength or permeability). In this case, Portland cement alone will be used for the treatability testing. Portland cement is expected to increase pH to reduce solubility of the metals while also creating a low permeability matrix. ISS would be used and will only be tested on source material, and the testing will be performed in parallel with the other treatability testing activities.

For this project a low dose and high dose will be tested. Each dose has a slightly different objective. The low dose would be designed to immobilize the metals, reduce permeability of the soils but not create a solid monolith. The higher dose is designed to achieve the same objectives and to create a solid monolith. By testing both doses, more options are available for the pilot and full-scale applications. Proposed doses and preliminary testing are provided in Table 4-5.

Table 4-5 Doses and Preliminary Testing for ISS Testing

ISS Type	Portland Cement Dose	Leachability Goal	Permeability Goal	Unconfined Compressive Strength Goal
Low Dose	0.5 to 1%	Cd, Be, and Ni below goals	<1.0x10-5 cm/sec	None, but data will be collected for information
High Dose	3 to 6%	Cd, Be, and Ni below goals	<1.0x10-6 cm/sec	> 50 psi

Blending will be conducted using saturated soil from the site. Testing will start with the lowest dose in each range shown in the table. Depending on initial results, additional higher or lower doses will be prepared.

Samples from each test will first be homogenized using a large spoon. The necessary soil and Portland cement weights will be measured with a scale. Portland cement will be pre-blended with a measured volume of potable water to create a thick slurry (approximately a one to one ratio is anticipated). The Portland cement and soil will be thoroughly blended by hand. Blending will continue until the material is uniform in color and no clumps of unblended material are apparent. The approximate volume change between just soil and blended soil and Portland cement will be noted.

Once blending is complete, the material will immediately be placed in 3-inch by 6-inch forms. The forms will be carefully filled to minimize void spaces. Each test run will require filling of five forms (three unconfined compressive strength [UCS] tests [at 7, 14, and 28-day intervals], one permeability test, and one leachability test). Upon filling, the forms will be capped and placed in a cooler. Samples will be sent to a geotechnical laboratory for UCS and permeability testing. The geotechnical laboratory will store the samples in a cooler and run the UCS testing at the 7, 14, and 28-day intervals. Once the UCS lower goal of 50 psi is achieved, the extra form will be tested for permeability. The testing regimen is provided in Table 4-6.

Table 4-6 ISS Laboratory Testing Schedule

Trial	7-day UCS	14-day UCS	28-day UCS	Permeability after 28 days	Leachability after 28 days
Low dose	1	1	1	1	1
High dose	1	1	1	1	1

Based on the first set of results (low dose 0.5% and high dose 3% additional trials may be conducted to better refine the minimum dose to meet the objective. Additional testing of the best ISS blends is also proposed, based on recommendations from ITRC guidance for ISS (2011). The specific tests proposed are summarized in Table 4-7.

Table 4-7 Laboratory Testing for ISS Trials

Test	Desired Result	Recommendation
Hydraulic Conductivity-ASTM 5084-90	Low dose <1.0x10-5 High dose <1.0 x10-6 cm/sec	Part of initial trials
Unconfined Compressive Strength- ASTM D1633	Low dose no criteria High dose >50 psi to <200 psi	Part of initial trials
Paint Filter Test, EPA Method 9095A	No free liquid	None. Not applicable to this situation
Wet/Dry Cycle, ASTM D4843	Not applicable to low dose No more than 10% loss	Only on best blend
Untreated Soil Whole Sample Leaching Test (modified pre-treatment EPA Method 1315m) see discussion below	Not applicable to low dose No more than 10% loss for high dose	Only on best blend
Treated Soil Whole Sample Leaching Test (modified EPA Method 1315m)	To determine mass flux/rate of release of metals (see discussion below)	Only on best blend

The whole sample leaching (Leaching Environmental Assessment Framework [LEAF]) test provides mass transfer release rates of constituents through low permeability material under diffusion-controlled release conditions. The method involves submerging the test sample in water, letting it sit, and periodically renewing the water. Samples are transferred to fresh reagent water at nine pre-determined intervals and eluate concentrations are plotted as a function of time. A control sample consisting of untreated soil is also tested. The untreated soil is compacted into a permeable form. The whole sample leaching test is later used in conjunction with site groundwater flow information to calculate the mass flux of metals leaving the stabilized area. The eluate from the leaching test will also be analyzed for physical chemistry parameters, such as pH and ORP. This information is used to assess whether GWPS are likely to be met in downgradient groundwater of a treated soil.

4.7 Quality Assurance/Quality Control

The laboratory analyses performed in support of the treatability test will be conducted using a combination of direct-read instrumentation, colorimetric test kits, and laboratory analyses. Samples for which the primary source of potential error is related to changes in sample conditions due to holding times will be performed by the treatability testing laboratory, and analyses requiring specialized analytical instrumentation will be performed by Eurofins Test America, using the procedures described in the GAF QAF and SAPs associated with the EIP and the SAP provided in Appendix B.

Treatability testing lab procedures are provided in Appendix D**.**

5. Field Demonstration Concept

The design of the field demonstration is dependent on the results of the Treatability Test and the Field Investigation results. Therefore, following completion of the Treatability Test and Field Investigation, a Field Demonstration Work Plan will be developed for TDEC's review and approval. The Field Demonstration Work Plan will present a detailed plan for implementing the field demonstration. There are several general approaches that are being considered for the field demonstration and eventual remedial implementation. These general approaches, their design considerations, and the data gaps that need to be addressed by the treatability test and field investigation area discussed herein.

5.1 Objectives of the Field Demonstration

The objectives of the field demonstration are to design and implement a groundwater remediation approach that will reduce groundwater concentrations to below GWPS in a pilot test treatment area. As indicated in Section 1.0, the Order specifies that the field demonstration be designed to adjust pH and meet GWPS along the NRS boundary compliance points adjacent to the Cumberland River, and therefore, much of the field demonstration will be focused at a location in that area. However, the field demonstration may include pilot testing activities in other locations (e.g., source treatment).

5.1.1 Field Demonstration Performance Standards

Specific performance standards for the field demonstration will depend on the location and nature of the demonstration element. Performance standards for source treatment will differ from those for plume treatment. Final performance standards will be established in the Field Demonstration Work Plan. However, preliminary performance standards for potential elements of the field demonstration are presented below.

One or more pilot remedies will be tested that target a reduction in metals concentrations along a downgradient edge of the NRS. The performance standards for this will likely include the following:

- Successful emplacement of permeable reactive barrier (PRB), possibly incorporating a partial hydraulic barrier, that intercepts contaminated groundwater flow through the unconsolidated deposits between the water table and bedrock;
- Attainment of GWPS for metals at compliance wells screened within the alluvium at the NRS boundary,
- Maintenance of groundwater potentiometric surface conditions over the period of demonstration such that bypass flow around the remedy is not apparent; and
- Sustained effectiveness for reduction in target metals concentrations over the period of the demonstration.

One or more source area remedies may be tested that target a reduction in flux of acidified groundwater and metals into the alluvial aquifer. The performance standards for this might include any of the following, depending on the nature of treatment:

- Successful implementation of soil mixing to increase pH or ISS of source material sufficient to achieve GWPS for metals immediately downgradient (or beneath) the source treatment; and
- Sustained effectiveness for reduction in concentrations over the period of the demonstration.

More specific performance standards will be developed for each element of the field demonstration as part of the Field Demonstration Work Plan, which will be submitted following the conclusion of treatability testing.

5.1.2 Field Demonstration Interim Benchmarks

It is anticipated that interim benchmarks will be specific dates for attainment of the following milestones:

- Commencement of field demonstration construction,
- Completion of field demonstration construction,
- Reduction in target metals concentrations downgradient of the field demonstration pilot areas,
- Attainment and maintenance of treatment objectives downgradient of the field demonstration pilot areas, and
- Submittal of annual progress reports and the field demonstration completion report.

A conceptual schedule for several of the above benchmarks is provided in Section 7. Dates will be updated in the Field Demonstration Work Plan.

5.1.3 Additional Field Demonstration Evaluation Criteria

While the purpose of the field demonstration is to identify a remedial measure that will adjust pH sufficient to attain GWPS along the NRS boundary, the results of the field demonstration will be incorporated into a comprehensive CARA Plan for closure of the NRS and remediation of groundwater. The CARA Plan will include evaluation of NRS closure elements that are not the subject of the field demonstration and may include alternative means of performing groundwater remediation, depending on the results of the field demonstration. Additional criteria to be considered in evaluating the effectiveness of the field demonstration, in this context, include the following:

- Time to achieve and maintain pH conditions sufficiently close to neutral to achieve treatment goals for metals,
- Time to achieve and maintain GWPS of target metals,
- Changes in non-target metals concentrations,
- Duration of effectiveness,
- Long-term stability of groundwater flow relative to the *in-situ* treatment area,
- Efficacy of delivery method (installation challenges, O&M requirements),
- Need and timing for reinjection or regeneration of in-situ treatment, and
- Cost.

5.2 Remedial Application Options for pH Adjustment

A number of remedial application approaches are under consideration for the field demonstration. The nature of the applications will be dependent upon the specific remedial amendment and the purpose of treatment in a given area (i.e., source treatment or plume treatment). Some remedial amendments are best applied as solids, whereas others can be introduced as liquids or slurries. The selection of remedial amendment and design considerations for the field demonstration (e.g., how much of the remedial amendment must be introduced to the subsurface to be effective) will be determined based on the treatability testing. The following describes some of the potential approaches to conducting a field demonstration to achieve source area or plume treatment.

5.2.1 Direct Injection of Remedial Amendments

Remedial amendments might be directly injected to effect source treatment (i.e., pH neutralization) or to generate a reactive zone for plume treatment. The feasibility of this approach is dependent on the physical characteristics of the remedial amendment and the hydrogeology of the aquifer materials into which direct injection is being performed. Because the alluvium that comprises the bulk of the unconsolidated deposits is a low-permeability formation, the prospects for direct injection of sufficient remedial amendment to perform an effective direct injection for plume treatment are limited. However, in the source area, where fill material is expected to have higher permeability than the alluvium, this may prove an appropriate means of introducing a remedial amendment to adjust pH.

Data requirements necessary to evaluate the feasibility and to design a direct injection remedy include determining the necessary remedial amendment dosage and its longevity *in situ*, determining the extent of influence of injected materials and injection spacing, and understanding the extent of area over which treatment will be required to be effective. This requires characterization of subsurface hydrogeology and the nature and extent of contamination in the treatment zone, in addition to the data being obtained from the laboratory treatability testing. The field investigation activities described in Section 3.0, and treatability testing activities described in Section 4.0 are intended to supplement existing data to meet these needs.

5.2.2 Permeable Reactive Barrier

PRBs are engineered subsurface installations constructed in such a way as to intercept a groundwater plume and treat groundwater as it flows through the barrier. PRBs can be constructed by physical mixing of remedial amendments with soil, by injection of remedial amendments from a series of soil borings, or by excavation of soil and emplacement of remedial amendments mixed with native soil or sand. PRBs are often installed in conjunction with hydraulic barriers to redirect groundwater flow through the reactive barrier (i.e., funnel and gate technology).

Data requirements for PRB installation for pH adjustment include those necessary to understand the following:

- The remedial amendment dosage necessary to overcome the acidity of the groundwater flowing through the barrier,
- The thickness of the barrier necessary to provide adequate and lasting groundwater treatment, given the groundwater flow velocity and acidity of groundwater; and
- The vertical and horizontal extent of the groundwater plume requiring treatment.

The installation of a PRB downgradient of the NRS may involve changing the geology of the perimeter dike of the NRS (e.g., replacing a portion of the clay alluvium with concrete sand). In such a case, the design of the PRB will need to include geotechnical considerations to maintain dike stability.

AECOM experience with PRBs is that those installed by injection are subject to greater limitations than those that involve direct mixing of soil or excavation and emplacement. Injected barriers are thinner barriers and sometimes turn out to be discontinuous. Because pH adjustment is a bulk process affected by the geochemistry of groundwater as a whole, it is likely to require a thicker barrier than a PRB designed to treat a relatively minor constituent of groundwater as is the case in many groundwater contaminant plumes.

Installation of a PRB by soil mixing or excavation has several advantages compared to injections. The primary advantages are more accurate delivery of reagents, better control of hydraulics (limiting the potential for groundwater to flow around the treatment chemicals), and ability to deliver a greater amount of reagent. PRB installation by soil mixing or excavation and emplacement has depth limitations. For example, a one-pass trench, wherein soil is removed and a PRB mixture emplaced simultaneously, the effective depth of treatment is limited to 30 to 50 feet, depending on the size of the one-pass trenching machine. The effective depth of direct soil mixing is generally less than 30 feet. While these depths can be increased by benched soil excavations, that is unlikely to be employed along the perimeter dike of the NRS. Because the groundwater plume extends to a depth of 60 feet or more in some areas, the installation of a PRB by one-pass trenching may need to be supplemented with a hydraulic barrier, like an injected grout curtain, which would extend from bedrock to the bottom of the PRB.

5.2.3 In-Situ Stabilization

ISS involves the direct-mixing or injection of solidifying agents into the subsurface. ISS has applications to both source treatment and plume containment. ISS can be an effective remedial measure in three primary ways. It reduces the leachability of solids that are incorporated into the solidified matrix; it reduces the permeability of the treated area, limiting the ability for groundwater to pass through and form a plume; and it raises the pH of the groundwater in the treatment area due to the chemistry of the ISS amendments (e.g., Portland cement, fly ash).

ISS could be applied in any of the following ways:

- As a means of stabilizing the source material itself and prevention of the generation of acidic groundwater;
- As a barrier beneath, around or downgradient of the source material to prevent migration of acidic groundwater;
- As an element of another remedial approach to help direct groundwater toward a treatment area or extraction point.

Data appropriate to support design of an ISS remedy or pilot test include those that can be obtained by bench testing of ISS reagents with site soil to determine optimal ISS amendment mixtures and specific dosing requirements. In addition, to implement ISS in the field, characterization of the treatment zone is necessary to identify the depth and extent of materials to be treated by ISS, whether that be in the source area or groundwater plume. The field investigation activities described in Section 3.0, and treatability testing activities described in Section 4.0 are intended to supplement existing data to meet these needs.

5.2.4 Groundwater Treatment-Based Remedies

Remedies that incorporate groundwater extraction and ex-situ treatment might also be considered for treatment of acidic groundwater and elevated metals concentrations, although a field demonstration may not be practical. This could be implemented as a simple groundwater extraction and treatment system or could be performed as a recirculation cell, wherein groundwater is extracted, amended to address the low pH and elevated metals issues and then reinjected with surplus treatment capacity to treat acidic groundwater *in-situ* and thereby speed the cleanup of the aquifer.

In addition to some of the data being developed by the planned treatability test, data necessary to implement a groundwater treatment-based remedy include a detailed understanding of NRS hydrogeology, including groundwater gradients and flow paths, aquifer transmissivity, and interconnection between the alluvial aquifer, the bedrock aquifer, and the Cumberland River, particularly in the areas where groundwater is being extracted or reinjected. Additional field investigation activities, beyond those proposed in Section 3.0, may be performed to develop the data necessary to design a groundwater treatment-based remedy, should such an approach be considered followed completion of the treatability test.

5.2.5 Other Remedial Considerations

The above remedies might be combined to develop an integrated remedy that combines elements of source treatment or containment and elements of plume treatment or containment. In addition, any of the above remedies might be combined with capping of the NRS to prevent infiltration of rainwater through the ash and management of stormwater to limit the infiltration of water through pyrite-rich source materials.

While such considerations are not directly applicable to the performance of the field demonstration, consideration of potential site-wide remedies will inform the planning and design for the field demonstration project, as well as ongoing investigation activities designed to better characterize the NRS.

5.3 Potential Field Demonstration Target Areas

There are several areas that appear suitable to perform the field demonstration. These locations and some of the considerations applicable to performing a pilot test in those areas are discussed below.

5.3.1 Upgradient Source Area

While discrete source material for the acidic conditions that promote elevated metals concentration has not been delineated, the general area around well GAF-441U has been identified as a potential source area upgradient of the NRS (Section 2.3, Figure 2-5). Depending on the results of additional characterization (see Section 3.0), a field demonstration to help assess the feasibility of source-area treatment could be performed. This potential source area is located near the eastern corner of the NRS in the vicinity of boring NRS035 where soil pH <5 was observed at several depth intervals, boring NRS036 where soil pH <5 was observed at several depth intervals and pyritic sulfur was detected in shallow soil, and well 441U where acidic groundwater has been observed and metals concentrations are the highest of the NRS wells (Figure 2-5).

5.3.2 Well 19R Area

Well 19R is a groundwater compliance well for the NRS and samples display both low pH and elevated metals concentrations in groundwater. Well 19R is screened in the alluvium downgradient of the ash disposed in the NRS. Low pH and elevated metals have also been observed in alluvial groundwater at adjacent well S3 and boring NRS007 (Figure 2-5). Soil pH <5 has also been observed in this general area. This area is generally downgradient of the potential source area. It is anticipated that a field demonstration effort will be performed in the well 19R area.

5.3.3 GAF-444U Area

Well GAF-444U is located at the southeastern end of the NRS, upgradient of the discharge channel and downgradient of the potential source area. Elevated metals concentrations and low pH have been detected in groundwater samples from well GAF-444U. This area is a potential field demonstration area. Additional investigation is proposed in Section 3.0 to evaluate the suitability of this area for a field demonstration pilot test.

6. Reporting

The following reports will be prepared in relation to the field demonstration project.

6.1 Treatability Test Report

A treatability test report will be prepared and submitted to TDEC at completion of the laboratory-based treatability study. The treatability test data will be compiled, evaluated, and the results discussed in the context of application of the remedial amendments at the NRS. The report will assess treatability test execution with respect to the objectives and performance standards identified in Section 4.1. The treatability report will identify chemical design parameters (e.g., one or more reagents, dosing rates, etc.) for the field demonstration.

6.2 Field Investigation Report

The field investigation report will be prepared and submitted to TDEC to document the results of the field investigation and provide the basis for the physical design parameters for the field demonstration. The field investigation data will be integrated with existing NRS data and evaluated in this report to recommend final locations for field demonstration, reagent delivery method(s), target zones within the saturated matrix, and supporting information for evaluation of the field demonstration. The field investigation report may also make recommendations for additional data gathering to further develop the CSM regarding the NRS in support of the CARA Plan. If additional investigation activities are recommended, those will be provided in a supplemental field investigation work plan. The field investigation report may be included with the treatability test report.

6.3 Field Demonstration Work Plan

Following completion of the treatability test and field investigation described herein, a Field Demonstration Work Plan will be prepared that incorporates the findings of the proposed treatability study and field investigation and details the following:

- The remedial amendments to be applied in the field demonstration,
- Field demonstration pilot areas and the nature of the pilot testing activities in each area,
- Health and safety concerns that may be unique to the demonstration,
- Access and site preparation,
- Construction activities, including any specialty subcontracted services,
- Performance monitoring well network locations and design,
- Initial start-up tasks and system operation tasks,
- System performance monitoring tasks, and
- A monitoring plan, as described in the following subsection.

The field demonstration work plan will include submittal of appropriate permit applications necessary to perform the work (e.g., Underground Injection Control Permit),

6.4 Monitoring Plan

The Order requires TDEC approval of a monitoring plan prior to commencement of the field demonstration project. It is anticipated that the monitoring plan will be incorporated into the field demonstration project. The plan must specifically include continued monitoring of groundwater and discharge locations in the Cumberland River identified in the EAR. Samples are required to be analyzed for CCR parameters (listed in 40 CFR Part 257, Appendices III and IV), and the parameters copper, nickel, silver, vanadium, and zinc (required by the state groundwater monitoring program).

Additional monitoring will be conducted in a well network designed specifically for the field demonstration project. The monitoring plan will identify a schedule for baseline and routine performance monitoring for each aspect of the field demonstration project. Parameters including pH and other water quality indicators will be measured, as well as any non-target inorganic analytes and/or byproducts of the selected treatment processes. It is anticipated that many of the analyses identified in Table 3-1 will be included.

Both the regulatory compliance and field demonstration performance monitoring network and analytical parameters will be identified in this Monitoring Plan.

6.5 Interim Annual Reporting

Subsequent to the approval of the Field Demonstration Work Plan, an annual report will be provided to TDEC describing progress of the field demonstration and presenting monitoring data obtained within the prior year. The interim annual reports will also identify field investigation activities that are being performed in the NRS in parallel with the field demonstration, but those results will be presented separately. Additional details on the interim annual reports will be provided in the Monitoring Plan (see Section 6.4)

6.6 Corrective Action/Risk Assessment Plan

In accordance with the Order, the Field Demonstration and the final EAR will provide the foundation for the CARA Plan for NRS closure and groundwater remediation. As appropriate, the CARA Plan is expected to include:

- Method(s) to remove and/or close-in-place CCR material at the NRS;
- Method(s) to remediate CCR-contaminated soil, surface water, and groundwater at the NRS;
- Methods to restore any natural resources damaged as a result of the CCR wastewater treatment and on-site CCR disposal;
- A plan for monitoring the air and water in the area during the cleanup process;
- A plan to ensure that public and private water supplies are protected from CCR contamination and that alternative water supplies are provided to local citizens if CCR contamination above GWPS is detected at drinking water sources;
- A plan addressing both the short-term and long-term management of CCR at the NRS, including remediation and stabilization of the NRS with design drawings and appropriate supporting engineering calculations; and
- A schedule of activities to be completed by TVA.

The CARA Plan will be developed upon completion of the Field Demonstration and will include a comprehensive evaluation of remedial alternatives beyond those considered in the field demonstration project. The evaluation and planning of the final remedial approach presented in the CARA Plan will consider technical feasibility and risk related to conditions that are expected to be present following the closure of the NRS, and the closure plan will present a solution that is protective of human health and the environment.

7. Schedule

The estimated duration of tasks for the treatability test and field demonstration is presented below and summarized in Figure 7-1. Time periods are referenced from the receipt of TDEC approval of the treatability test workplan.

- Kickoff, mobilization: **weeks 1-3.**
- Collection of groundwater and potential treatment zone soil samples for use in treatability testing: **weeks 4-8.**
- Performance of field investigation activities and additional treatability study sample collection: **weeks 5-16.**
- Performance of batch testing of selected reagents and selection of amendments for microcosm testing: **weeks 6-10.**
- Completion of microcosm testing of reduced set of reagents and selection of amendments for column testing **weeks 10-20.**
- Finalization of design parameters for column testing, based on the preliminary results of the field investigation: **weeks 20-22.**
- Completion of column testing and selection of reagents and delivery methods for field demonstration: **weeks 20-40.**
- Submittal of treatability test report and field investigation report: **weeks 32-52**
- Preparation of field demonstration workplan and monitoring plan: **weeks 32-56.**
- TDEC review and approval of Field Demonstration Work Plan and monitoring plan and permit issuance: **weeks 56-68.**
- Field demonstration construction: **weeks 68-100.**
- Field demonstration monitoring: **weeks 100-260.**

The above durations are estimates. The interim benchmark for completion of the treatability testing is the submittal of the treatability test report, which is anticipated by one year after approval of this workplan is received from TDEC. The schedule of events beyond the submittal of the Field Demonstration Work Plan will be dependent on TDEC review of any permits required for performance of the field demonstration.

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  GAF Draft EAR Section 5.3.1 CCR Chemistry and Leachability
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Tables

Table 4-3: Analytical Strategy

Testing Stage	Field tests (DO, ORP, pCO2, Fe species) lab tests (TKN, S species, alkalinity)	Water: Target Metals (Cd, Be, and Ni)	Water: pH	Water: Other field parameters (DO, ORP)	Water: Target Metals and Other Metals	Water: Secondary Parameters Inorganic/Physical Parameters & As species (if As present)	Precipitate: Target Metals and Other Metals	Soil: Applicable Parameters from Table 3-1	Soil or Precipitate: Sequential Extraction (Cd, Be, Li, Ni, & Iron)*	Soil or precipitate: Mineral Analysis**
Raw Groundwater/ Soil	3							1		
Titration screening		10	10	10						
Best reagents from titration test					5	5	5		Optional if sufficient precipitate is present	Optional if sufficient precipitate is present
Microcosm screening		5	5	5						
Best reagents from microcosm					3	3		3	Optional	Optional
Column testing - Site soil and sand trials[1]		72	72	72				8 - one from each column at the end of test		
Best reagents from column test	3				24	24			2 or 3 most successful columns[2]	2 or 3 most successful columns[2]
Triaxial column testing		TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Notes:

Table depicts estimated minimum number of samples of each type. Additional tests with a reagent may be performed.

Specific analyte list may be modified, based on individual reagent (e.g., phosphate will not be analyzed if it is not added as part of a reagent).

Detailed analyte lists for listed analyses are provided in Table 3-1.

[1] Column testing; assuming 3 reagents per trial plus one control per trial, three ports, 4-time intervals.

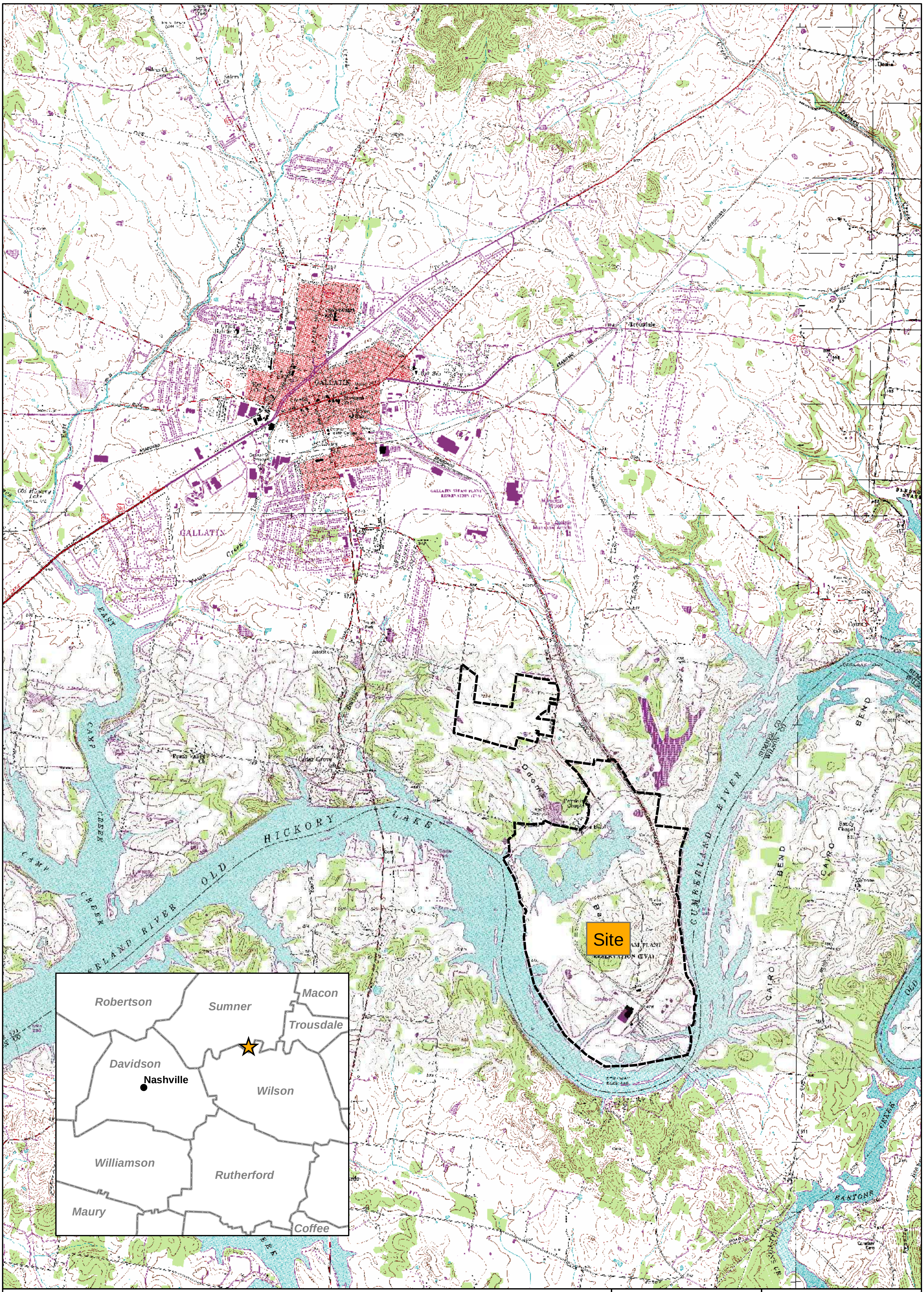
[2] Site soil and sand and controls at the end of test.

Colorimetric test kits will be used when possible to test for redox sensitive species.

* Sequential extraction is designed to provide information on mobility of metals after treatment and insights into which minerals may be forming.

** The value of conducting this category of testing will be evaluated as initial test data becomes available. These are designed to determine which minerals are present in the treated samples in comparison to untreated samples. This would provide data on the anticipated longevity of the minerals. These methods may include x-ray diffraction, x-ray fluorescence, scanning electron microscopy, and x-ray photoelectron spectroscopy.

Figures



LEGEND

▭ TVA Gallatin Fossil Plant Property Boundary (Approximate)

N

0 4,000 8,000

Feet

NOTE: USGS 7.5' Topographic Quadrangle Maps (Portions)-Cottontown 1994, Hendersonville 1968, Gallatin 1955, Laguardo 1955, Bethpage 1994, and Hunters Point 1994.

Figure 1-1

Gallatin Fossil Plant
(GAF) Location Map

DRAWN BY:	REVIEWED BY:	APPROVED BY:	REVISION NUMBER:
MARK.P.SMITH	SCHEIPC		REV. 3

GALLATIN FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DATE:	DEPT:
8/14/2017	FOSSIL AND HYDRO ENGINEERING

LEGEND

→ Cumberland River Direction of Flow

🟧 Non-Registered Site

▭ TVA Gallatin Fossil Plant Property Boundary (Approximate)

N

0 1,200 2,400

Feet

NOTE: Aerial image dated February 2017

AECOM

Figure 1-2

NON-REGISTERED SITE (NRS)
LOCATION MAP

DRAWN BY:	REVIEWED BY:	APPROVED BY:	REVISION NUMBER:
MARK.P.SMITH	M. STAUFFER		REV. 0

GALLATIN FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DATE:	DEPT:
9/4/2019	FOSSIL AND HYDRO ENGINEERING

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LEGEND

- ▨ Asbestos Landfill Limit
- 🟧 CCR Management Units
- ☐ 2000' Grid
- 🟫 NRS Cell Boundary
- ⬚ TVA Gallatin Fossil Plant Property Boundary (Approximate)

NOTE: Aerial image dated February 2017

N

0 400 800
Feet

AECOM

Figure 1-3

NON-REGISTERED SITE (NRS)
OPERATING AREAS

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GALLATIN FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DATE:	DEPT:
9/5/2019	FOSSIL AND HYDRO ENGINEERING

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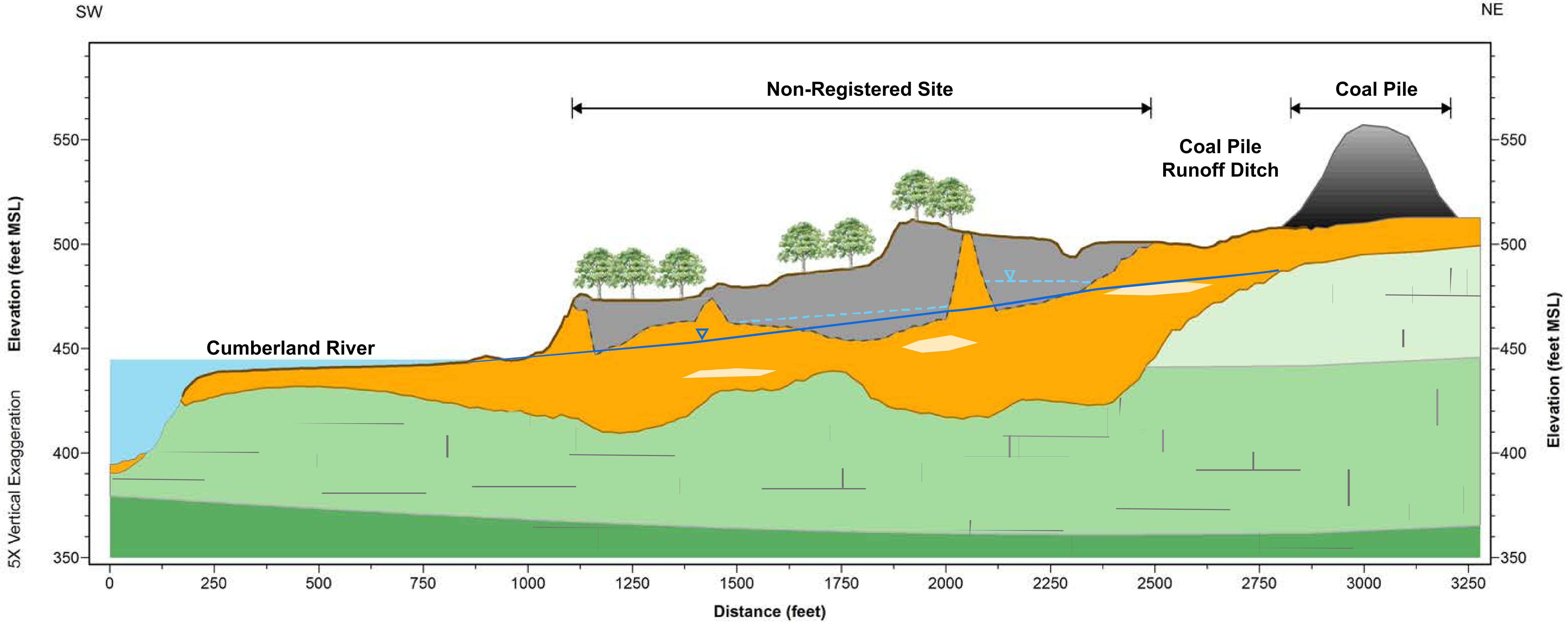

LEGEND

- ▨ CCR
- ▨ Sand / Gravel
- ▨ Silt / Clay
- ▨ Lower Carters Limestone
- ▨ Lebanon Limestone
- ▨ Ridley Limestone
- — Ground Surface
- — Top of Rock (Dashed Where Approximate)
- — Geologic Contact (Dashed Where Approximate)
- ▨ Cumberland River
- - - Phreatic Surface in CCR
- - - - Approximate Lower Limit of CCR

NOTE: Cross section is schematic to show conceptual model and may not represent a specific physical location

- ▽ Groundwater Table in Alluvium
- | Hypothetical Fractures

AECOM

Figure 2-1

CONCEPTUAL GEOLOGIC
CROSS SECTION -NRS

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GALLATIN FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DATE: 9/23/19
DEPT: FOSSIL AND HYDRO ENGINEERING

Document Path: Q:\DCS\Projects\L-URS\Jobs4_Projects\TVA\Gallatin_General\EIP\11.0 GIS\geologic_cross_sections\MXD\NRSRev0\NRS Conceptual Hydrogeo Model.mxd

NOTE: Aerial image dated February 2017

LEGEND:

GAF-444U
449.88
Well Screened in Unconsolidated Deposits and Groundwater Elevation June 10, 2019 (ft amsl)

GAF-445L
446.26
Well Screened in Lebanon Limestone and Groundwater Elevation June 10, 2019.

Historic Well (Limited Data Available)

GAF-405C
482.22
Well Screened in Carters Limestone and Groundwater Elevation June 10, 2019

GAF-442A
486.64
Well Screened in Ash and Phreatic Surface Elevation June 10, 2019

1A
485
Seep and Ground Surface Elevation (ft amsl)

× Historic Boring
× Abandoned Well
● CPT Location
CCR Management Units
Hydrogeologic Cross Section Location
Groundwater Table Contour (ft amsl) in Unconsolidated Deposits

Estimated Extent of Lower Carters Limestone Aquifer
Estimated Extent of Groundwater in Unconsolidated Deposits
The Lebanon Aquifer Exists throughout the Map Area

0 200 400
Feet

AECOM

Figure 2-2

GROUNDWATER ELEVATIONS WITH POTENTIOMETRIC CONTOURS IN UNCONSOLIDATED DEPOSITS

DRAWN BY:	REVIEWED BY:	APPROVED BY:	REVISION NUMBER:
MARK.P.SMITH	M.STAUFFER		REV. 0

GALLATIN FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DATE:	DEPT:
9/6/2019	FOSSIL AND HYDRO ENGINEERING

19R	Concentration Range (ug/L)	Exceedance Frequency
Beryllium	8.38 - 14.1	20/20
Cadmium	4.55 - 12.4	19/20
Nickel	124 - 321	20/20
pH	3.2-3.9	--

Constituent	GWPS (ug/L)
Beryllium	4
Cadmium	5
Nickel	100

LEGEND

🟫	Soil Stockpile
▨	Coal Pile
▨	Unconsolidated Deposits of Disturbed Native Alluvium, Fill and Mixture of Alluvium/Fill
🟧	Unconsolidated Deposits of Clay Alluvium with Isolated Sand Stringers, Residuum
⬜	CCR
🟩	Lower Carters Limestone
🟩	Lebanon Limestone
🟩	Ridley Limestone
—	Ground Surface
—	Top of Rock (Dashed Where Approximate)
—	Geologic Contact (Dashed Where Approximate)

Boring or Well

Well Screen (shaded with formation type where projected onto cross-section)

▼	Estimated Potentiometric Surface in Unconsolidated Deposits June 2019 (dashed where inferred)
▽	Observed Phreatic Surface in Ash, June 10, 2019
- - -	Potentiometric Contour (feet MSL)
→	Groundwater Flow Direction
422.25	Groundwater Elevation (ft msl) June 10, 2019

Notes:
1. Lithology and top of rock interpretations at boring locations are based on boring logs and borehole geophysical data. Top of rock interpretations between borings are based on outcrops and topography.
2. Ground surface elevations derived from the 2017 LIDAR and 2016 River Bathymetry surveys.
3. Sampling data (range of pH and analytical results) based on data collected from October 2016 through July 2019.
4. NS = not sampled
5. GWPS = groundwater protection standards
6. When both unfiltered (total) and filtered (dissolved) samples were collected, both values were compared to the GWPS. If the filtered sample did not exceed the GWPS, the unfiltered sample exceedance was attributed to turbidity and is not included in the count of exceedance frequency.
7. Unfiltered (total) analytical results are presented on this figure. Analytes that exceeded the GWPS in the unfiltered samples only are not presented.
8. < GWPS = Sampled analytes were below GWPS.

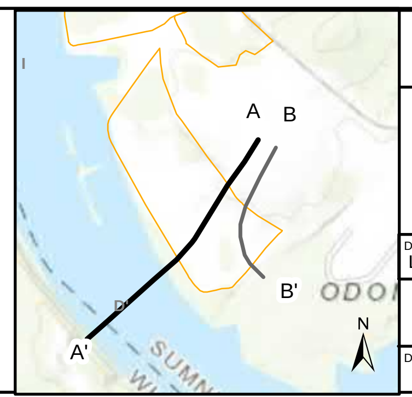

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Figure 2-3

HYDROGEOLOGIC CROSS SECTION A-A'
NRS

DRAWN BY:	REVIEWED BY:	APPROVED BY:	REVISION NUMBER:
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GALLATIN FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DATE: 9/24/2019
DEPT: FOSSIL AND HYDRO ENGINEERING

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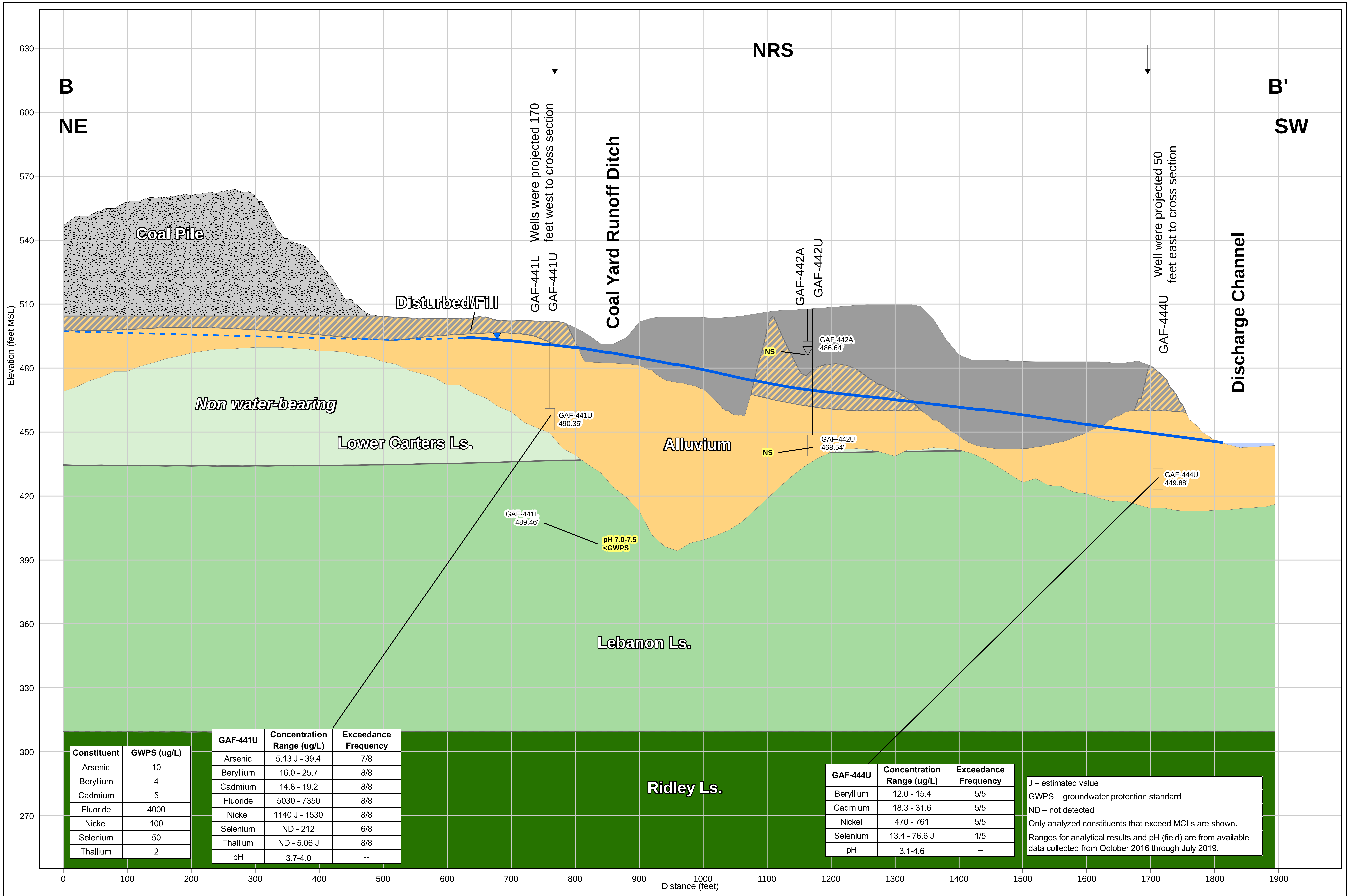


Constituent	GWPS (ug/L)
Arsenic	10
Beryllium	4
Cadmium	5
Fluoride	4000
Nickel	100
Selenium	50
Thallium	2

GAF-441U	Concentration Range (ug/L)	Exceedance Frequency
Arsenic	5.13 J - 39.4	7/8
Beryllium	16.0 - 25.7	8/8
Cadmium	14.8 - 19.2	8/8
Fluoride	5030 - 7350	8/8
Nickel	1140 J - 1530	8/8
Selenium	ND - 212	6/8
Thallium	ND - 5.06 J	8/8
pH	3.7-4.0	--

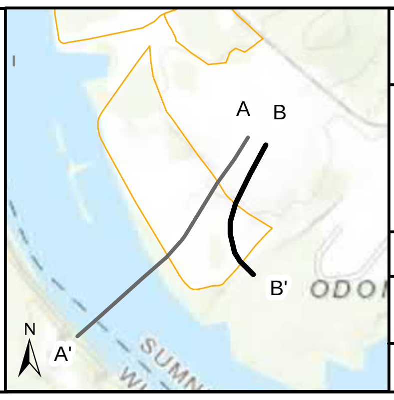
GAF-444U	Concentration Range (ug/L)	Exceedance Frequency
Beryllium	12.0 - 15.4	5/5
Cadmium	18.3 - 31.6	5/5
Nickel	470 - 761	5/5
Selenium	13.4 - 76.6 J	1/5
pH	3.1-4.6	--

J – estimated value
GWPS – groundwater protection standard
ND – not detected
Only analyzed constituents that exceed MCLs are shown.
Ranges for analytical results and pH (field) are from available data collected from October 2016 through July 2019.

LEGEND

🟫	Soil Stockpile
▨	Coal Pile
▨	Unconsolidated Deposits of Disturbed Native Alluvium, Fill and Mixture of Alluvium/Fill
🟧	Unconsolidated Deposits of Clay Alluvium with Isolated Sand Stringers, Residuum
⬛	CCR
🟩	Lower Carters Limestone
🟩	Lebanon Limestone
🟩	Ridley Limestone
—	Ground Surface
—	Top of Rock (Dashed Where Approximate)
—	Geologic Contact (Dashed Where Approximate)
	Boring or Well
▯	Well Screen (shaded with formation type where projected onto cross-section)
▼	Estimated Potentiometric Surface in Unconsolidated Deposits June 2019 (dashed where inferred)
▽	Observed Phreatic Surface in Ash, June 10, 2019
- - -	Potentiometric Contour (feet MSL)
➔	Groundwater Flow Direction
422.25	Groundwater Elevation (ft msl) June 10, 2019

Notes:
1. Lithology and top of rock interpretations at boring locations are based on boring logs and borehole geophysical data. Top of rock interpretations between borings are based on outcrops and topography.
2. Ground surface elevations derived from the 2017 LIDAR and 2016 River Bathymetry surveys.
3. Sampling data (range of pH and analytical results) based on data collected from October 2016 through July 2019.
4. NS = not sampled
5. GWPS = groundwater protection standards
6. When both unfiltered (total) and filtered (dissolved) samples were collected, both values were compared to the GWPS. If the filtered sample did not exceed the GWPS, the unfiltered sample exceedance was attributed to turbidity and is not included in the count of exceedance frequency.
7. Unfiltered (total) analytical results are presented on this figure. Analytes that exceeded the GWPS in the unfiltered samples only are not presented.
8. < GWPS = Sampled analytes were below GWPS.



AECOM

Figure 2-4

HYDROGEOLOGIC CROSS SECTION B-B'
NRS

DRAWN BY:	REVIEWED BY:	APPROVED BY:	REVISION NUMBER:
LANCE.GREENE	M. STAUFFER	KEYSV	REV. 1

GALLATIN FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DATE: 9/24/2019
DEPT: FOSSIL AND HYDRO ENGINEERING

Document Path: M:\EnvDataViz\TVA\11.0 GIS\geologic_cross_sections\MXD\NRSRev3\NRS_BB_201908v2.mxd

LEGEND:

GAF-441U PH < 5

GAF-438L PH ≥ 5

✳ METAL(S) CONCENTRATION ≥ GWPS

✳ METAL(S) CONCENTRATION < GWPS

◕ Monitoring Well Location

× Historic Boring

× Abandoned Well

▭ CCR Management Units

— Hydrogeologic Cross Section Location

■ Seep

N

0 200 400
Feet

Notes:
1. If no designation is shown on map for monitoring location, then the data are not available.
2. Approximate locations are shown for seep locations AECOM-001, AECOM-002, CDA-1-1, CDA-1-4, TVA-2E2, and TVA-2D.
3. GWPS - groundwater protection standard.
4. < - less than
5. ≥ - greater than or equal to
6. If both unfiltered (total) and filtered (dissolved) samples were collected concurrently, both values were compared to the GWPS. If the filtered sample did not exceed the GWPS, the unfiltered sample exceedance was attributed to turbidity and is not considered an exceedance of the GWPS.
7. pH and analytical data collected in 2011 (GP-1 to GP-6) or during one or more sampling investigations conducted between April 2015 to July 2019.
8. Aerial image dated February 2017

AECOM

Figure 2-5

DISTRIBUTION OF METALS AND PH IN
GROUNDWATER SAMPLES

DRAWN BY:	REVIEWED BY:	APPROVED BY:	REVISION NUMBER:
MARK.P.SMITH	M .STAUFFER		REV. 0

GALLATIN FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DATE: 9/6/2019
DEPT: FOSSIL AND HYDRO ENGINEERING

LEGEND

●	Monitoring Well Location
●	Groundwater Profiling
●	Proposed Boring Location
▨	Asbestos Landfill Limit
☐	CCR Management Units
GAF-489U	Proposed Groundwater Sampling Location in the Unconsolidated Deposits
*	Proposed Slug Test Location

N

0 400 800
Feet

NOTE: Aerial image dated February 2017

Document Path: Q:\DCS\Projects\L-URS\Jobs4_Projects\TVA\Gallatin\NRS 2019 Work Plan\900_CAD_GIS\920 - GIS\MXD_report\FIELD_SAMPLING_LOCATIONS_ALT.mxd

AECOM

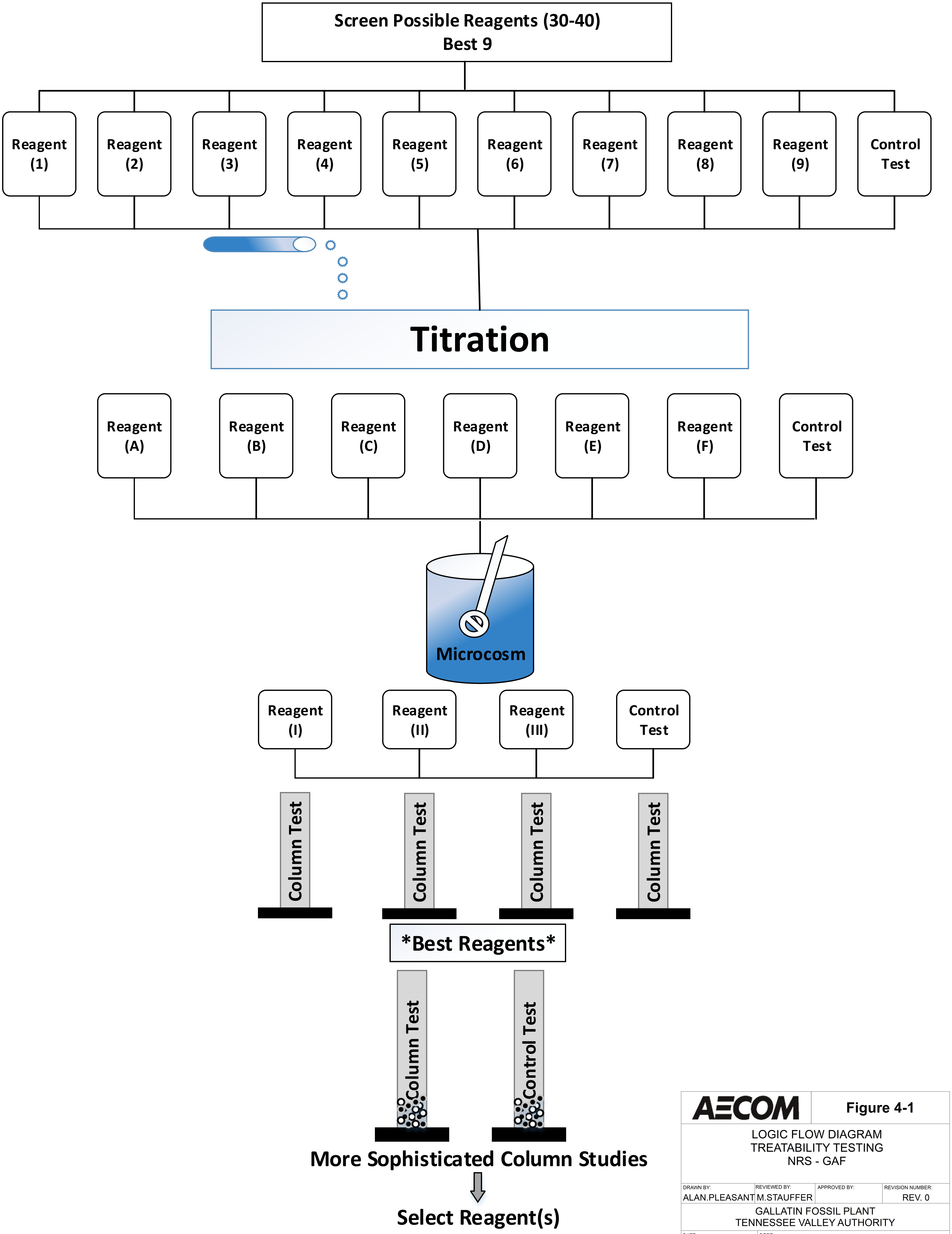
Figure 3-1

FIELD INVESTIATION
SAMPLING LOCATIONS

DRAWN BY:	REVIEWED BY:	APPROVED BY:	REVISION NUMBER:
MARK.P.SMITH	M.STAUFFER	M.STAUFFER	REV. 9

GALLATIN FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DATE:	DEPT:
9/24/2019	FOSSIL AND HYDRO ENGINEERING



AECOM

Figure 4-1

LOGIC FLOW DIAGRAM
TREATABILITY TESTING
NRS - GAF

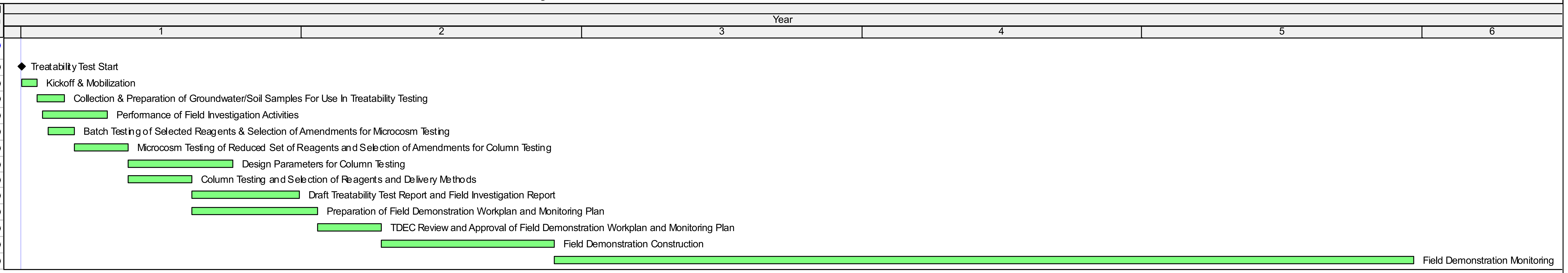
DRAWN BY:	REVIEWED BY:	APPROVED BY:	REVISION NUMBER:
ALAN.PLEASANT	M.STAUFFER		REV. 0

GALLATIN FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DATE:	DEPT:
8/14/2019	FOSSIL AND HYDRO ENGINEERING

Overall Project Schedule

Activity Name	Original Duration
GAF - NRS Remediation Treatability Test Work	260w
Treatability Test Start	0w
Kickoff & Mobilization	3w
Collection & Preparation of Groundwater/Soil Samples For Use In Treatability Testing	5w
Performance of Field Investigation Activities	12w
Batch Testing of Selected Reagents & Selection of Amendments for Microcosm Testing	5w
Microcosm Testing of Reduced Set of Reagents and Selection of Amendments for Column Testing	10w
Design Parameters for Column Testing	20w
Column Testing and Selection of Reagents and Delivery Methods	12w
Draft Treatability Test Report and Field Investigation Report	20w
Preparation of Field Demonstration Workplan and Monitoring Plan	24w
TDEC Review and Approval of Field Demonstration Workplan and Monitoring Plan	12w
Field Demonstration Construction	33w
Field Demonstration Monitoring	160w



First Year Project Schedule

Activity Name	Original Duration
GAF - NRS Remediation Treatability Test Work	260w
Treatability Test Start	0w
Kickoff & Mobilization	3w
Collection & Preparation of Groundwater/Soil Samples For Use In Treatability Testing	5w
Performance of Field Investigation Activities	12w
Batch Testing of Selected Reagents & Selection of Amendments for Microcosm Testing	5w
Microcosm Testing of Reduced Set of Reagents and Selection of Amendments for Column Testing	10w
Design Parameters for Column Testing	20w
Column Testing and Selection of Reagents and Delivery Methods	12w
Draft Treatability Test Report and Field Investigation Report	20w
Preparation of Field Demonstration Workplan and Monitoring Plan	24w

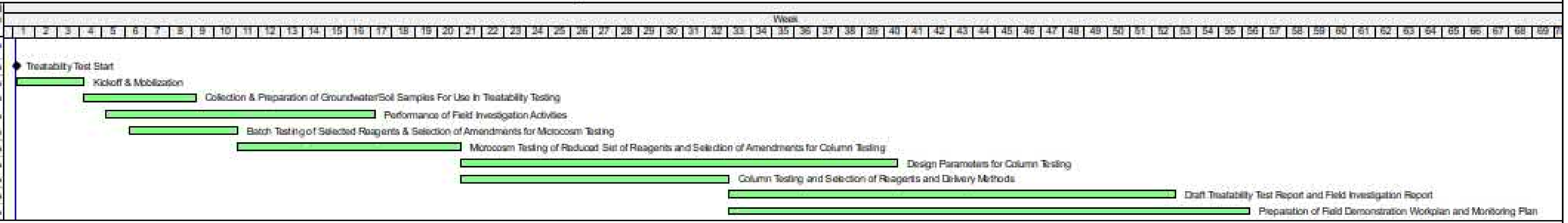


Figure 7-1
Anticipated Schedule
NRS Treatability Test and Field Demonstration
TVA Gallatin Fossil Plant

Note 1: These tasks are alternate scope items.
Note 2: The ROR/RAP dates are reflective of an approved alternate scope addition and can potentially occur sooner if not approved/implemented.

Appendix A
NRS Groundwater pH Adjustment Screening Bench Study

Tennessee Valley Authority
Gallatin Fossil Plant

NON-REGISTERED SITE GROUNDWATER PH ADJUSTMENT SCREENING BENCH STUDY

Chattanooga, Tennessee

September 27, 2019

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ATTACHMENTS

ACRONYMS AND ABBREVIATIONS

µg/L	Micrograms per Liter
µS/cm	MicroSiemens per Centimeter
% wt	Percent by Weight
AECOM	AECOM Technical Services, Inc.
Al	Aluminum
AM	AQUAMAG®
Be	Beryllium
C	Celsius
CCR	Coal Combustion Residuals
Cd	Cadmium
Cr	Chromium
DO	Dissolved Oxygen
EAR	Environmental Assessment Report
EB	EnviroBlend®
FB	FerroBlack®-H
FBS	FerroBlack®–Solids
Fe	Iron
FeS_2	Pyrite
GAF	Gallatin Fossil Plant
g/L	Grams per liter
MCL	Maximum Contaminant Level
Mg	Magnesium
Mg/L	Milligrams per Liter
Mn	Manganese
Mo	Molybdenum
mV	Millivolts
Na	Sodium
NaOH	Sodium Hydroxide
Ni	Nickel
NRS	Non-Registered Site #83-1324

NTU	Nephelometric Turbidity Units
ORP	Oxidation-Reduction Potential
P	Phosphorus
Pace	Pace Analytical Laboratories
Pb	Lead
REDOX TECH	REDOX TECH, LLC
SU	Standard Units
TVA	Tennessee Valley Authority
V	Vanadium
Zn	Zinc
ZVI	Zero Valent Iron

EXECUTIVE SUMMARY

The Tennessee Valley Authority (TVA) is conducting an environmental investigation at the Gallatin Fossil Plant (GAF) facility, and provided an interim Environmental Assessment Report (EAR) to the State of Tennessee in April 2017 (TVA, April 2017). The interim EAR concluded that, while further study is needed to determine the appropriate groundwater corrective action at the Non-Registered Site (NRS), the use of a pH adjustment strategy appears to be a feasible and effective groundwater corrective action technology to mitigate potential maximum contaminant level (MCL) exceedances in the alluvium at the NRS. This technical memorandum presents the results of the initial screening test and identifies data needs for further evaluation of potential corrective action options for water in the alluvium underlying the NRS.

Concentrations of beryllium (Be), cadmium (Cd), and nickel (Ni) are above Tennessee MCLs in Well 19R. In localized areas, groundwater in overburden has also been affected by low pH. Wells 19R and GAF-441U, screened within overburden materials, have acidic groundwater (median pH of 3.79) compared to the median groundwater pH of 6.27 for the other two overburden wells. In general, acidic water more readily dissolves and mobilizes metals than neutral water. Acidic conditions promote transformation of metals from solid (adsorbed, precipitated, or co-precipitated) forms to dissolved forms that are transportable in water. Therefore, pH adjustment is a potentially feasible groundwater corrective action to mitigate MCL exceedances in the NRS alluvium.

The objectives of the screening test were to: (1) demonstrate removal of Be, Cd, and Ni from NRS water samples to meet applicable standards, and (2) to provide a decision-basis for the development of additional pre-design studies. The amendments tested included:

- Three strong bases (sodium hydroxide [NaOH], EnviroBlend® [EB], and AQUAMAG® [AM]) intended to promote precipitation of (oxy)hydroxides of iron (Fe), aluminum (Al), and manganese (Mn), which are potentially effective matrices for adsorption of Be, Cd, and Ni.
- Zero valent iron (ZVI), a "combination reagent" that moderately raises solution pH (mineral precipitation/adsorption strategy), weathers to form Fe (oxy)hydroxides (adsorption strategy), and lowers oxidation-reduction potential (ORP) (potential sulfide precipitation strategy).
- FerroBlack®-H (FB), a "combination reagent" that provides a source of free sulfides while strongly lowering ORP (Ni/Cd-sulfide precipitation strategy), and has the potential to create a modest increase in pH to favor Be adsorption.

Approximately 25 gallons of water were collected from Well 19R and shipped to the REDOX TECH, LLC, laboratory in Cary, North Carolina. REDOX TECH subcontracted Pace Analytical Laboratories for analytical services. Metals and other inorganic chemical and physical parameters, which are routinely analyzed in the NRS assessment program, were analyzed in samples of unfiltered and

filtered water in the control (untreated) sample and in aliquots of filtered and unfiltered water obtained after reactions with the amendments. Precipitation was expected as an outcome of these tests, and adequate volumes of precipitate (solids) were retrievable following filtration. The solids samples were analyzed for the same metals analyzed in aqueous samples.

Solution pH manipulation was the common strategy among the tested treatments, and the magnitude of the pH-related results was: NaOH (8.5 standard units [SU]) > EB (7.3 SU) > FB (5.8 SU) > ZVI (4.8 SU) > AM (3.5 SU) > control (3.1 SU). Most of the reactions occurred within several hours of adding the treatment amendments, and pH was not affected by filtration of the sample.

Increasing pH had a beneficial effect on metals removal, particularly at pH values above neutral (pH 7), which was readily achieved in the NaOH and EB treatments. The aqueous sample data indicated that successful treatment (i.e., reduction to concentrations below Tennessee MCLs) of Be, Cd, and Ni (target metals/constituents) was achieved in the NaOH and EB treatments, and partial success of one or more of these constituents was achieved with ZVI and FB. Successful treatment was not achieved in the AM treatment or the control. Be and Cd were treated to or below applicable standards in both filtered and unfiltered samples collected from EB, FB, NaOH, and ZVI reactors. Ni was treated to below standards in both the filtered and unfiltered samples collected from the EB, FB, and NaOH amended reactors. The Ni concentration was below the applicable standard in the filtered sample from the ZVI reactor, but not in the unfiltered sample.

In addition to target metal removal, the mobilization of non-target metals is an important side effect that should be considered in future testing and remedy selection. Metals addition in one form or another related to each reagent is expected, such as Fe for ZVI and FB and phosphorous (P) addition for AM. However, AM treatment also resulted in increased concentrations of Mo and vanadium (V), which were not detected in the Well 19R samples. An increase of V was also observed in filtered and unfiltered samples of FB and the unfiltered sample of ZVI. Unfiltered water from FB and ZVI treatment had increased chromium (Cr) and V; FB (unfiltered) water also had increased Mn, molybdenum (Mo), and zinc (Zn). None of the increases of mobilized metals in the filtered or unfiltered samples resulted in concentrations that exceeded the relevant regulatory standard.

The NaOH and EB treatments were effective at removing significant mass of Be, Cd, and Ni from the aqueous (filtered) and suspended (unfiltered) phases of the reacted samples. ZVI and EB generated the highest amount of solids followed by NaOH, FB, and AM. The amount of solids that are added or that precipitate as a result of the reagent treatments is an important consideration since solid placement and mineral precipitation may reduce hydraulic conductivity within the aquifer and negatively impact *in-situ* treatment performance.

The screening study met the treatment objectives of proving that pH adjustment can change the dissolved state of target metals. However, treatments that provide successful short-term results in jar tests may only have a temporary effect *in-situ*, where acids can leach back in from the soil matrix.

Additional studies using NRS alluvium soil as well as groundwater, and the two to three most promising amendments selected from the screening study, are recommended to continue assessing the performance and dosage requirements. Data from laboratory tests should then be evaluated along with site-specific information on water flow through the alluvium and location-specific low pH conditions within the NRS to determine the potential benefits of implementing an *in-situ* pilot study.

1 INTRODUCTION

The Tennessee Valley Authority (TVA) is conducting an environmental investigation at the Gallatin Fossil Plant (GAF) facility. TVA provided an interim Environmental Assessment Report (EAR) to the State of Tennessee in April 2017 (TVA, April 2017). The EAR will be utilized to support the development of an appropriate corrective action plan, if necessary, for GAF. The interim EAR concluded that, while further study is needed to determine the appropriate groundwater corrective action at the Non-Registered Site (NRS), the use of a pH adjustment strategy appears to be a feasible and effective groundwater corrective action technology to mitigate potential maximum contaminant level (MCL) exceedances in the alluvium at the NRS.

TVA authorized AECOM Technical Services, Inc. (AECOM) to conduct an initial screening to test the pH adjustment concept using water collected from a NRS compliance monitor well using several amendments. The tests represent a proof of the treatment concept, under conditions simplified to assess only groundwater and potential beneficial or detrimental changes in chemistry due to additives and/or processes (e.g., a “jar” test). Additives and/or processes that indicate potential to reduce target metal concentrations, and not create adverse groundwater chemical reactions, may be carried forward for further testing.

AECOM evaluated and selected five amendments with potential to successfully reduce target metals in GAF NRS groundwater. AECOM contracted REDOX TECH, LLC (REDOX TECH) of Cary, North Carolina, to perform the screening test. REDOX TECH obtained the selected amendments, performed the tests in their laboratory using GAF NRS water provided by AECOM, and subcontracted an analytical laboratory to perform the inorganic analyses selected by AECOM.

This technical memorandum presents the results of the initial screening test and identifies data needs for further evaluating potential corrective action options for water in the alluvium underlying the NRS.

2 BACKGROUND

The NRS served as the initial GAF coal ash disposal unit until 1970. Available data indicate that groundwater does not generally appear to be flowing into the NRS from upgradient areas. There is little groundwater present in overburden upgradient of the NRS, and it is largely limited to an area off the southeast corner of the NRS. Although these conditions may change during wet periods or locally beneath the deeper portions of the NRS, based on the limited extent of overburden groundwater upgradient from the NRS and the very low permeability of the overburden, potential seasonal inflow from the groundwater, if any, is likely to be insignificant (TVA, April 2017).

TVA has been conducting post-closure groundwater monitoring at the NRS since about 2000. In 2009, monitoring entered the Assessment phase, due to concentrations of beryllium (Be), cadmium (Cd), and nickel (Ni) in Well 19R above Tennessee MCLs. There are two primary findings related to groundwater chemistry in the vicinity of the NRS:

- Groundwater beneath the NRS has been impacted by coal combustion residuals (CCR) constituents, which have migrated from the NRS into the underlying groundwater in both the overburden and limestone bedrock.
- In more localized areas, groundwater in overburden has also been affected by low pH and elevated metals.

Wells 19R and GAF-441U, screened within overburden materials, have acidic groundwater (median pH of 3.79) compared to the median groundwater pH of 6.27 for the other two overburden wells, and compared to the NRS ash pore water. The highest sulfate concentrations also occur at these two wells. Therefore, factors specific to these locations (and not extending to other areas) appear to be responsible for the low pH, elevated sulfate, and concurrent metals concentrations. One potential source of both acidity and sulfate is oxidation of pyrite (FeS_2) or pyritic minerals, which may be present in the NRS as a result of Illinois Basin coal use. It is also possible that the runoff in the coal yard runoff ditch had a low pH in the past due to pyrite weathering from the coal pile (which was lined to minimize leakage during NRS closure activities). The interim EAR provides additional historical operational information and data evaluation of potential sources causing acidic conditions. **Attachment A** presents recent assessment data from Well 19R.

In general, acidic water more readily dissolves and mobilizes metals than neutral water. Acidic conditions can increase the mobility of metals, promoting transformation from solid (adsorbed, precipitated, or co-precipitated) forms to dissolved forms that are transportable by acidic water. Therefore, pH adjustment is a potentially feasible groundwater corrective action to mitigate MCL exceedances in the NRS alluvium.

3 SCREENING TEST OBJECTIVES

The objectives of the screening test were to: (1) demonstrate removal of Be, Cd, and Ni from NRS water samples, and (2) to provide a decision basis for the development of additional pre-design studies. The target metals for the tests have exceeded applicable or relevant groundwater protection standards in groundwater from Monitoring Well 19R **(Attachment A)**. The tested amendments were selected based on their potential to remove the targeted metals from groundwater by adsorption, (co)precipitation, or a combination of these processes. The amendments tested are identified in **Table 1**, and included:

- Three strong bases that were intended to promote precipitation of (oxy)hydroxides of iron (Fe), aluminum (Al), and manganese (Mn), which are potentially effective matrices for adsorption of Be, Cd, and Ni. These reagents were aqueous sodium hydroxide (NaOH), EnviroBlend® (EB), and AQUAMAG® (AM);
- Zero valent iron (ZVI), a “combination reagent” that moderately raises solution pH (mineral precipitation/adsorption strategy), weathers to form iron (oxy)hydroxides (adsorption strategy), and lowers oxidation-reduction potential (ORP) (sulfide precipitation strategy).
- FerroBlack®-H (FB), a “combination reagent” that provides a source of free sulfides while strongly lowering ORP (Ni/Cd-sulfide precipitation strategy), and has the potential to create a modest increase in pH to favor Be adsorption.

Information on the providers of these amendments is included in **Attachment B**. In addition, only products with an “off-the-shelf” level of availability were tested; products that are currently in development or that could be customized for application at the Site were not evaluated.

The fraction of target metals that remain in solution (in filtered samples) and suspension (unfiltered) samples was analyzed at the completion of each test. The quantity and the composition of solid precipitate after the reaction with the added reagents were also analyzed. These analyses are intended to facilitate a preliminary interpretation of the processes that are important for the removal of Be, Cd, and Ni from aqueous solution and elucidate some of the “side effects” associated with the tested geochemical strategies.

4 FIELD SAMPLE COLLECTION

Water was collected from NRS Monitoring Well 19R on Tuesday July 11, 2017. Approximately 25 gallons of water were collected and placed in five 5-gallon plastic carboys that previously contained de-ionized water. No preservation, specific shipping or handling, or chain-of-custody procedures were required except for keeping the water cool during shipment. The carboys were placed in coolers and chilled, and shipped to the REDOX TECH laboratory in Cary, North Carolina, for receipt on July 12, 2017. The containerized water was received intact.

The field parameters of temperature, pH, conductivity, dissolved oxygen (DO), ORP, and turbidity were measured during collection. The final measured water quality parameters for the water collected from Well 19R are noted below.

- Temperature: 16.6 degrees Celsius (C)
- pH: 3.88 Standard Units (SU)
- Conductivity: 2632 MicroSiemens per Centimeter (µS/cm)
- DO: 2.86 milligrams per liter (mg/L)
- ORP: 161.7 milliVolts (mV)
- Turbidity: 115 Nephelometric Turbidity Units (NTU; ranged from 45 to 130 during collection)

These data were provided to REDOX TECH as information prior to test initiation.

5 ANALYTICAL PLAN

REDOX TECH subcontracted Pace Analytical Laboratories (Pace) for analytical services. **Table 2** presents the analytical plan. All parameters identified in **Table 2** were analyzed in samples of unfiltered and filtered water in the control (untreated) sample and in aliquots of filtered and unfiltered water obtained after reactions with the amendments identified in **Tables 1 and 2**.

Precipitation was expected as an outcome of many of these tests. Adequate volumes of precipitate were retrievable following filtration, and a solids sample was obtained and analyzed for the physical parameters identified on **Table 2**.

6 TEST PROCEDURES

As stated in Section 3, the objectives of the tests were to evaluate if the addition of any of the amendments removed Be, Cd, and Ni from aqueous solution, and to evaluate changes in groundwater chemistry as they may affect further testing and, potentially, the design of a remedy. This test was not designed to understand the correct amendment dosing requirements for a specific amendment and target analyte concentration in groundwater. Test procedures used by REDOX TECH are in their report included as **Attachment B**.

Upon receipt of the samples, water in the field containers was homogenized at the REDOX TECH facility to facilitate setup of the screening tests. The homogenized groundwater was used to set up one control reactor (i.e., with no amendments) and five batch reactors with the five amendments identified in Section 3.

Treatment doses of 10 grams per liter (g/L) for AM, EB, FB, and ZVI treatments and 2.6 ml/L (3.3 g/L) for the 25 percent weight (% wt) NaOH aqueous solution were added to Well 19R water in one-gallon commercial, distilled water containers (jugs). The groundwater and reagents were mixed by vigorously inverting the one-gallon jugs for approximately 30 seconds twice per day. Reactions were allowed to occur for at least 48 hours, after which filtered and unfiltered samples were extracted from the containers and sent to a subcontracted laboratory (Pace) for analysis using Method 6010. Solid residues in the reaction jugs and sample filters were combined for each treatment and air-dried before also sending to a subcontracted laboratory for preparation and total elemental analysis using Methods 3050 and 6010, respectively.

7 RESULTS AND DISCUSSION

7.1 RESULTS AND DISCUSSION

Appendix C of the REDOX TECH report **(Attachment B)** includes the laboratory reports of water and solid samples analyzed for these tests.

Results on **Figure 1** show the following observations:

- The evaluated treatments resulted in a variety of 48-hour solution pH values between 3 and 8 SU
- Most of the reactions occurred within several hours of adding the treatment amendments
- pH was not affected by filtration of the sample
- At the tested doses, the NaOH and EB treatments achieved a solution pH greater than 7 SU after 24 hours

The data presentation on **Table 3** indicate that successful treatment of Be, Cd, and Ni was achieved in the NaOH and EB treatments, and partial success of one or more of the target constituents was achieved with ZVI and FB. Successful treatment was not achieved in the AM treatment or the control. Be and Cd were treated to or below applicable standards in both filtered and unfiltered samples collected from EB, FB, NaOH, and ZVI reactors. Ni was treated to below standards in both the filtered and unfiltered samples collected from the EB, FB, and NaOH amended reactors. Ni concentration was below the applicable standard in the filtered sample from the ZVI reactor, but not in the unfiltered sample.

Table 3 is color-coded to show concentration reductions (green, yellow, red) or increases (blue) relative to the control sample. Parameters are arranged by category, and metals with initial concentrations of 1 micrograms per liter (µg/L) or more are arranged in order of precipitation or adsorption that typically occurs with increasing pH (Smith, 1999). The color coding on **Table 3** visually indicates that geochemical changes induced by the added reagents varied among treatments and among constituents.

The data presented on **Table 3** are reduced in **Table 4** to represent the percentage of concentration reduction that was achieved by treatment relative to the observed concentration reductions in the control. The relative magnitude of the starting concentration is also indicated to help gauge the relative significance of the observed reductions. As shown in **Table 4**, concentrations of metals in the samples from NaOH and EB treatments had more than 90 percent reduction of Be, Cd, and Ni compared to the control sample. Large increases in aqueous concentrations of magnesium (Mg) in EB treatment and sodium (Na) in NaOH and AM treatments were also observed. Complete or nearly complete reductions of Fe, Mn, and Al were observed in the strong base treatments using NaOH and EB.

A mass balance was performed by comparing the mass removed from aqueous samples (initial concentrations minus final concentrations) to the total elemental analysis data obtained on solid-phase precipitates from each treatment. Details of the mass balance are included as **Table 5,** and are summarized by the graphs included on **Figure 2** and **Figure 3**. As shown on **Figure 2**, the NaOH and EB treatments were effective at removing significant mass of Be, Cd, and Ni from the aqueous (filtered) and suspended (unfiltered) phases of the reacted samples.

7.2 DISCUSSION

The manipulation of solution pH was the common strategy among the tested treatments, and the pH-related results shown on **Figure 1** indicate that the magnitude of the 48-hour solution pH was: NaOH (8.5 SU) > EB (7.3 SU) > FB (5.8 SU) > ZVI (4.8 SU) > AM (3.5 SU) > control (3.1 SU). Increases in pH in the strong base treatments NaOH and EB were consistent with the anticipated chemistries, while the pH after 48 hours for the AM treatment was much lower than expected, and may have been a result of low dosing or slow dissolution of the strong-based components. Increasing pH had a beneficial effect on metals removal, particularly at pH values above neutral (pH 7 SU), which was readily achieved in the NaOH and EB treatments. The unfiltered control sample contained 363 mg/L of Fe, 61.7 mg/L of Al, and 27.3 mg/L of Mn, almost all of which were removed from solution by the addition of strong base. These three metals precipitate and form adsorptive surfaces as pH increases to approximately 3.5 SU, 5.5 SU, and 8.5 SU, respectively. Lead (Pb) also readily adsorbs to iron oxyhydroxide at about pH 3.5 SU, while Be adsorbs to mineral surfaces at pH 6 SU, and Cd and Ni adsorb at pH of about 6.5 SU. Since nearly complete removal of Fe and Al from the aqueous phase was achieved in the higher pH treatments (as shown on **Table 4**), and was coupled with large increases in Fe and Al in the solid precipitates of these treatments (as shown on **Table 5**), it is likely that precipitates of these metals provided substrates for adsorption or co-precipitation of other metals. Mn precipitation may have been initiated and also served as a substrate for adsorption.

The manipulation of solution ORP and solution pH was a strategy used in the ZVI and FB treatments. As shown on **Figure 2**, significant reductions in Be, Cd, and Ni mass in the filtered and unfiltered samples was achieved. Reductive conditions promote precipitation of sulfide minerals; the target metals and lead are known to form sulfide minerals under appropriate redox (oxidation-reduction) and pH conditions. Reductive treatment is indicated by increased sulfide for FB batch tests and ZVI1. Non-detected sulfide for ZVIF2 may indicate that all sulfide was consumed by reactions, or was oxidized during filtration to obtain the sample for analysis. The filtered sample from FB treatment (FBF2) removed the targeted metals, probably due to their removal during filtration, and did not add other metals. This beneficial effect was achieved at a relatively low pH of 4.3 and apparently reducing conditions. In comparison with the unfiltered FB sample, the filtered sample filtration apparently removed much of the Fe from FBF2; the FBS (FerroBlack–Solids) precipitate consisted of 1.7 percent Fe, second in Fe content to ZVI precipitate (4.3 percent).

In addition to removal of target metals, the mobilization of non-target metals is an important “side effect” that should be considered in future testing and remedy selection. Metals addition in one form or another related to each reagent is expected, such as Fe for ZVI and FB and phosphorous (P) addition for AM. However, AM treatment also resulted in increased concentrations of molybdenum (Mo) and vanadium (V), which were not detected in Well 19R samples. Increase of V was also observed in filtered and unfiltered samples of FB and unfiltered sample of ZVI. Unfiltered water from FB and ZVI treatment had increased chromium (Cr) and V; FB1 (unfiltered) water also had increased Mn, Mo, and zinc (Zn). None of the increases of mobilized metals in the filtered or unfiltered samples resulted in concentrations that exceeded the relevant regulatory standard.

Other important "side effects" that should be considered in future testing and remedy selection include the amount of solids that are added or that precipitate as a result of the reagent treatments. The total mass of solids (undissolved reagent plus formed precipitate) recovered from each test was ZVI (34.4 g) > EB (29.4 g) > NaOH (10.4 g) > FB (5.8 g) > AM (3.4 g). This is important to consider since solid placement and mineral precipitation may affect (reduce) hydraulic conductivity within the aquifer and negatively impact treatment performance of an emplaced reagent.

8 SUMMARY AND RECOMMENDATIONS

In summary, three pH-based amendments (AM, EM, and NaOH) and two combination pH-ORP based amendments (FB and ZVI) were tested to evaluate their effectiveness in removing target metals in the site groundwater sample. The results indicate that EB, NaOH, and FB were able to reduce target metals to below applicable standards (both filtered and unfiltered samples). ZVI performed well in reducing Be and Cd in both filtered and unfiltered samples, and Ni in the filtered sample, but did not reduce Ni to below standard in the unfiltered sample. It is not clear if the dosage was sufficient for AM and ZVI, and if a different dosage may have resulted in better performance. ZVI and EB generated the highest amount of solids followed by NaOH, FB, and AM.

The screening study met the treatment objectives of proving that pH adjustment can change the dissolved state of target metals. However, treatments that provide successful short-term results in jar tests may only have a temporary effect *in-situ*, where slow-release formulations that can deliver amendment gradually would potentially have a more sustained positive effect. Additionally, acids could leach back in from the soil matrix.

For these reasons, a jar test that includes NRS alluvium soil as well as groundwater, and the two to three most promising amendments selected from the screening study, are recommended to continue assessing the performance, dosage requirements, and stability of precipitates if acidic groundwater re-enters the area. Data from laboratory tests should then be evaluated along with site-specific information on water flow through the alluvium and location-specific low pH conditions within the NRS. These additional evaluations would support the decision to implement a pilot study to evaluate *in-situ* feasibility (implementability, short and long-term performance).

9 REFERENCES

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Tables

Table 1
Amendments Tested
pH Bench Study
TVA Gallatin Fossil Plant, Gallatin, Tennessee

Targeted Process	Product Category	Trade Name/Company Name	Chemical Composition	Basis of Selection
pH Control	Caustic Slurry	Enviroblend®	Variable - "AQ" - $Mg(OH)_2$ with impurities (Brucite ore) "CS" - MgO, CaO and sesquioxides	Metals (e.g., Fe, Mn, Al) hydroxide precipitation with pH change, Cd and Ni adsorb to iron hydroxides/(oxy)hydroxides
pH Control	Caustic Solution	Not Applicable	$NaOH_{(aq)}$	Metal (e.g., Fe) hydroxide precipitation with pH change, Cd and Ni adsorb to iron hydroxides/(oxy)hydroxides
pH Control	Caustic Solution	AquaMag	$Mg(OH)_2$, PO_4	Metals hydroxide precipitation with pH change
Redox Control	Chemical Reductant	FerroBlack®	Iron sulfide compound	Sulfate reduction, Cd and Ni reduction and precipitation as metal sulfides.
Redox Control	Chemical Reductant	Zero-valent iron - varies	Fe(0)	Sulfate reduction, Cd and Ni reduction and precipitation as metal sulfides or co-precipitation and/or adsorption onto iron corrosion products.

Table 2
Analytical Plan
pH Bench Study
TVA Gallatin Fossil Plant, Gallatin, Tennessee

		Process Sample Source[1]																
		Untreated/Control[2]		Sodium Hydroxide (NaOH)			AquaMag			Zero Valent Iron (ZVI)			Ferro Black			EnviroBlend		
Sample Identification		CONT 1	CONT F2	NaOH 1	NaOH F2	NAOHS 10.41G	AM 1	AM F2	AMS 3.40G	ZVI 1	ZVI F2	ZVI 34.37G	FB 1	FB F2	FBS 5.79G	EB 1	EB F2	EB 29.38G
Target Compliance Metals	Analytical Method	Unfiltered	Filtered [1]	Aqueous - Unfiltered	Aqueous - Filtered	Solid Precipitate	Aqueous - Unfiltered	Aqueous - Filtered	Solid Precipitate	Aqueous - Unfiltered	Aqueous - Filtered	Solid Precipitate	Aqueous - Unfiltered	Aqueous - Filtered	Solid Precipitate	Aqueous - Unfiltered	Aqueous - Filtered	Solid Precipitate
Beryllium	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cadmium	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nickel	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Metals of Interest																		
Antimony	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Arsenic	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Barium	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chromium	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cobalt	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Copper	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fluoride	SW9056A	X	X	X	X		X	X		X	X		X	X		X	X	
Lead	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lithium	SW846 6020B/Prep 3010A	X	X	X	X		X	X		X	X		X	X		X	X	
Molybdenum	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Selenium	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Silver	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Thallium	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Vanadium	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Secondary Compliance																		
Aluminum	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chloride	SW9056A	X	X	X	X		X	X		X	X		X	X		X	X	
Iron (total)	SW846 6020B/Prep 3010A	X	X	X	X		X	X		X	X		X	X		X	X	
Manganese	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pH	SM4500-H+B	X	X	X	X		X	X		X	X		X	X		X	X	
Sulfate	EPA 300.0	X	X	X	X		X	X		X	X		X	X		X	X	
TDS	SM 2540C	X	X	X	X		X	X		X	X		X	X		X	X	
Zinc	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Physical/Inorganic																		
pH	Field/Lab Instrument Measured	X																
Dissolved Oxygen	Field/Lab Instrument Measured	X																
Temperature	Field/Lab Instrument Measured	X																
Turbidity	Field/Lab Instrument Measured	X																
Oxidation Reduction Potential	Field/Lab Instrument Measured	X																
Specific Conductivity	Field/Lab Instrument Measured	X																
Alkalinity, Total as CaCO3	SM 2320B	X	X	X	X		X	X		X	X		X	X		X	X	
Alkalinity,Bicarbonate (CaCO3)	SM 2320B	X	X	X	X		X	X		X	X		X	X		X	X	
Alkalinity, Carbonate (CaCO3)	SM 2320B	X	X	X	X		X	X		X	X		X	X		X	X	
Calcium	SW846 6020B/Prep 3010A	X	X	X	X		X	X		X	X		X	X		X	X	
Iron (Dissolved)	SW846 6020B/Prep 3010A	X	X	X	X		X	X		X	X		X	X		X	X	
Magnesium	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sodium	SW846 6020B/Prep 3010A	X	X	X	X		X	X		X	X		X	X		X	X	
Sulfide	SM4500 S2D	X	X	X	X		X	X		X	X		X	X		X	X	
Phosphorus	EPA 365.1	X	X	X	X		X	X		X	X		X	X		X	X	
Potassium	SW846 6020B/Prep 3010A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Total Solids	SM 2540B	X	X	X	X		X	X		X	X		X	X		X	X	
Total Volatile Solids	EPA 160.4	X	X	X	X		X	X		X	X		X	X		X	X	

Notes:

1. All samples to be filtered in the laboratory
2. To be collected in laboratory upon shipment receipt and filtration

Table 3
Treatment Results
pH Bench Study
TVA Gallatin Fossil Plant, Gallatin, Tennessee

Parameter	units	CCR GWPS (ug/L)	TN Solid Waste Management GWPS (ug/L)	NPDWR MCL (ug/L)	Cont1	ContF2 (filtered)	AM1	AMF2 (filtered)	ZVIF2 (filtered)	FBF2 (filtered)	ZVI1	FB1	NaOH1	NaOHF2 (filtered)	EBF2 (filtered)	EB1
pH	s.u.	NA	NA	6.5-8.5	3.0	3.0	3.1	3.2	3.7	4.3	5.5	6.0	7.5	7.5	7.6	7.9
sulfide	mg/L	NA	NA	NA	<0.10	<0.10	<0.10	<0.10	<0.10	0.88	0.21	15.7	<0.10	<0.10	<0.10	<0.10
sulfate	mg/L	NA	NA	250	2230	2400	2200	2070	2350	2740	2140	2270	2170	2550	2090	2140
Iron	ug/L	NA	NA	300	363,000	343,000	328,000	311,000	622,000	<118	669,000	593,000	3,060	762	138J	36,500
Dissolved Iron	ug/L	NA	NA	NA	370,000	347,000	233,000	231,000	579,000	387,000	613,000	403,000	17,100	<118	1,400	2,040
Lead	ug/L	15	15	15	**29.2**	**28**	11.2	3.5	<0.80	<0.80	0.98J	10	<0.80	<0.80	<0.80	<0.80
Copper	ug/L	NA	NA	1300	70.6	66.6	84.4	58.1	<1.2	<1.2	9.7	123	2.8J	<1.2	<1.2	<1.2
Aluminum	ug/L	NA	NA	50 -200	61,700	59,900	39,900	34,800	451	69.6J	5,870	49,500	526	77.8J	<67.0	340
Zinc	ug/L	NA	NA	5000	1,180	1,130	1,310	1,160	745	<24.0	885	2,180	<24.0	<24.0	<24.0	<24.0
Beryllium	ug/L	4	4	4	**11.8**	**11.5**	9.4	9.1	1	0.22J	3	4	<0.20	<0.20	<0.20	<0.20
Nickel	ug/L	NA	100	NA	**172**	**171**	164	164	65.2	<4.5	116	95.7	4.9J	<4.5	<4.5	15
Cobalt	ug/L	Background	NA	NA	321	312	295	295	200	0.29J	239	84	3.5	6.3	4.4	38.8
Cadmium	ug/L	5	5	5	**6.6**	**6.4**	5.7	5.9	1.7	<0.60	2.8	2	<0.60	<0.60	<0.60	1.1
Manganese	ug/L	NA	NA	50	27,300	27,600	25,500	22,700	28,300	12	28,300	31,700	4,220	8,470	8,560	15,500
Antimony	ug/L	6	6	6	<1.0	<1.0	1.0 J	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Silver	ug/L	NA	100	NA	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80
Thallium	ug/L	2	2	2	1.1	0.96J	0.50J	0.45J	<0.20	<0.20	<0.20	0.27J	0.74J	0.72J	0.75J	0.87J
Arsenic	ug/L	10	10	10	2.3	2.1	3.4	3	0.77J	<0.50	1.3	1.8	<0.50	<0.50	<0.50	<0.50
Chromium	ug/L	100	100	100	<1.0	<1.0	2.1J	2.2J	<1.0	1.3J	6.5	92.6	<1.0	1.2J	1.2J	<1.0
Molybdenum	ug/L	Background	NA	NA	<1.1	<1.1	12.6	10.7	<1.1	<1.1	<1.1	14	<1.1	<1.1	<1.1	<1.1
Selenium	ug/L	50	50	50	26.5	25.9	21.1	19	10.2	<3.2	13.8	12.8	<3.2	<3.2	<3.2	<3.2
Vanadium	ug/L	NA	NA	NA	<0.70	<0.70	10.4	9.6	<0.70	3.5J	8.9	17.9	<0.70	<0.70	<0.70	<0.70
Barium	ug/L	2000	2000	2000	19	18.9	6.7	4.2	20.7	57.2	17.2	22.1	12.2	9.9	20.8	23.1
Calcium	ug/L	NA	NA	NA	499,000	491,000	454,000	448,000	496,000	5,610	480,000	540,000	464,000	486,000	475,000	493,000
Lithium	ug/L	Background	NA	NA	117	113	113	113	107	13.5J	108	61.2	109	99	117	118
Magnesium	ug/L	NA	NA	NA	28,200	27,900	26,100	26,300	28,200	3,780	27,000	29,300	18,700	23,200	272,000	281,000
Potassium	ug/L	NA	NA	NA	15,700	15,100	14,700	14,200	16,900	2,640	14,600	17,400	15,000	15,100	14,900	15,900
Sodium	ug/L	NA	NA	NA	10,400	10,400	1,120,000	953,000	12,600	7,540	10,700	837,000	558,000	572,000	11,300	11,100
alkalinity bicarb	mg/L	NA	NA	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	454	--	17.5	4.9J
alkalinity carb	mg/L	NA	NA	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	--	<1.0	<1.0
alkalinity total	mg/L	NA	NA	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	454	48.1	17.5	4.9J
phosphorous	mg/L	NA	NA	NA	.032J	.031J	857	827	.044J	.031J	0.055	0.065	.029J	<0.025	0.16	.032J
chloride	mg/L	NA	NA	250	2.9	2.9	4.3	4.7	4.2	804	2.9	755	3.1	4.3	5.8	5.3
fluoride	mg/L	4	4	4	0.4	0.37	0.26	0.22	0.18	<0.050	0.18	<0.050	0.29	0.24	.099J	0.11
Total Solids	mg/L	NA	NA	NA	3,760	3,920	6,650	7,190	1,920	980	3,980	6,750	5,620	727	3,660	4,440
Total Volatile Solids	mg/L	NA	NA	NA	700	630	140	950	250	132	795	1,410	615	54	620	748
Total Dissolved Solids	mg/L	NA	NA	500	3,390	3,200	5,280	5,730	3,690	4,620	3,680	4,540	3,530	3,450	2,960	3,310

Notes:
bold parameters exceeded GWPS in control samples.
Concentration decrease:
🟥
🟨
🟩
Concentration increase:
🟦
GWPS - Groundwater Protection Standard
MCL - Maximum Contamination Level
mg/L - milligram per liter
NA - Not Applicable/No MCL established
NPDWR - National Primary Drinking Water Regulations
-- not analized

Table 4
Percent Mass Removed by Treatment
pH Bench Study
TVA Gallatin Fossil Plant, Gallatin, Tennessee

	Starting Mass Order of Magnitude	Ferro Black	NaOH	Enviroblend	ZVI	AquaMag
Aluminum	100	99.9%	99.9%	*99.9%*	99.3%	42.8%
Arsenic	0.001	*77.2%*	*77.2%*	*77.2%*	65.2%	-36.4%
Barium	0.01	-201.8%	47.8%	-9.8%	-9.2%	77.8%
Beryllium	**0.01**	98.1%	*98.2%*	*98.2%*	91.4%	21.9%
Cadmium	**0.01**	*90.7%*	*90.7%*	*90.7%*	73.8%	9.2%
Calcium	1000	98.9%	1.8%	4.0%	-0.2%	9.5%
Cobalt	1	99.9%	98.0%	98.6%	36.8%	6.8%
Copper	0.1	*98.3%*	*98.3%*	*98.3%*	*98.3%*	15.3%
Iron	1000	*100.0%*	*100.0%*	99.6%	-64.0%	34.6%
Iron, Dissolved	1000	-7.9%	99.8%	100.0%	-73.5%	13.2%
Lead	**0.1**	*97.2%*	*97.2%*	*97.2%*	*97.2%*	87.8%
Magnesium	100	86.5%	17.3%	-869.7%	-0.5%	6.2%
Manganese	100	100.0%	69.1%	68.8%	-3.1%	17.3%
Nickel	**0.1**	*97.4%*	*97.4%*	*97.4%*	62.0%	4.4%
Potassium	10	82.9%	1.9%	3.2%	-9.7%	7.8%
Sodium	10	27.5%	-5400.0%	-8.7%	-21.2%	-9063.5%
Zinc	1	*97.9%*	*97.9%*	*97.9%*	35.5%	-0.4%

Notes:

The order of magnitude is presented to give a frame of reference for the magnitude of a percentage change.

Changes shown are for filtered (dissolved) phases of treated samples rather than unfiltered (suspended) phases of treated samples, and are relative to the Control.

Negative percentages indicate that a greater concentration of the parameter was present in the post-treatment aqueous sample than pre-treatment aqueous sample.

Orange highlights indicate significantly negative percentages (any exceptions are noted below).

Italics indicate the parameter was not detectable in the post-treatment aqueous sample, The value provided was calculated using the detection limit, therefore the values should be considered a minimum percent removed.

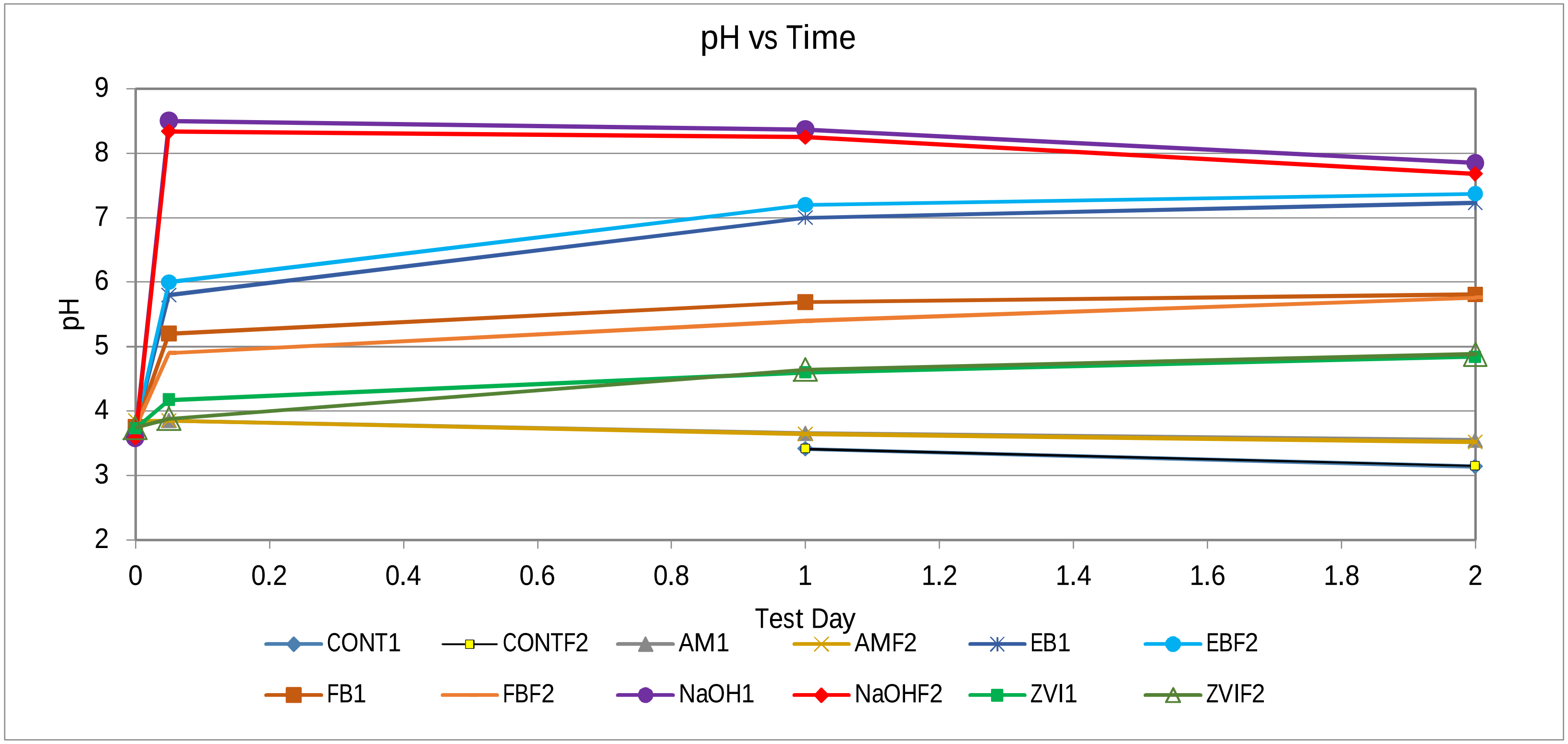
While barium had a -200% change for Ferro Black, the unfiltered sample was very close to the starting value, and so the increase in the filtered value is likely just variation considering the small amount of mass

Table 5
Percent of Mass Removed Present in Precipitate
pH Bench Study
TVA Gallatin Fossil Plant, Gallatin, Tennessee

	Starting Mass Order of Magnitude	Ferro Black	NaOH	Enviroblend	ZVI	AquaMag
Aluminum	100	125.9%	47.6%	*70.8%*	19.1%	61.1%
Arsenic	0.001	*801.7%*	*1247.0%*	*2422.5%*	6268.8%	-976.8%
Barium	0.01	-13.196%	82.0%	-671.3%	-67.4%	82.2%
Beryllium	**0.01**	33.5%	*45.7%*	*48.2%*	2.3%	66.9%
Cadmium	**0.01**	*17.4%*	*25.7%*	*38.2%*	5.1%	67.4%
Calcium	1000	0.5%	51.3%	551.1%	-105.3%	58.5%
Cobalt	1	47.6%	54.7%	51.2%	1550.9%	41.4%
Copper	0.1	*478.8%*	*37.9%*	*2.5%*	*1535.5%*	47.9%
Iron	1000	*75.0%*	*54.5%*	92.3%	-1743.6%	60.6%
Iron, Dissolved	1000	-928.5%	53.7%	90.5%	-1495.5%	155.6%
Lead	**0.1**	*99.0%*	*99.9%*	*159.1%*	*711.8%*	100.9%
Magnesium	100	1.2%	30.3%	-964.0%	-0.8%	44.0%
Manganese	100	2.8%	45.5%	82.2%	-40.0%	52.6%
Nickel	**0.1**	*92.5%*	*54.8%*	*56.2%*	2989.5%	76.6%
Potassium	10	80.0%	5032.6%	669.0%	-161.0%	340.6%
Sodium	10	178.1%	-1.3%	-186.3%	-54.9%	-0.7%
Zinc	1	*430.1%*	*70.0%*	*83.0%*	2.4%	-1789.2%

Notes:
Percentages greater than 100% indicate that there was more mass of a given parameter present in the precipitate than removed from the starting sample
Significantly higher percentages are highlighted blue. (any exceptions are noted below)
Higher negative percentages indicate that there is additional constituent present in the precipitate in addition to what appeared in the post-treatment aquesous sample, significantly more negative values are highlighted orange (any exceptions are noted below)
Italics indicate that the parameter was not detectable in the post-treatment aqueous sample, The value presented was calculated with the detection limit, therefore the values should be considered a maxium percent accumulation
Underlines indicate that the parameter was not detectable in the precipitate, so these values could be as low as 0%
High percentages based on the detection limit in the precipitate were not considered, as these could be as low as 0%
An increase in arsenic was shown in all post treatment samples. However, considering the low concentration of arsenic in the dissolved phase the percentages are likely inflated due to the difference in testing methods and not an actual accumulation of arsenic.
The increase of zinc using AquaMag was less than 1 percent, so the precipitate ratio is biased and therefore not highlighted
The accumulation of barium using Enviroblend is exaggerated based on the small volume of mass present, and was therefore was not highlighted

Figures



AECOM	**Figure 1**

PH VS TIME

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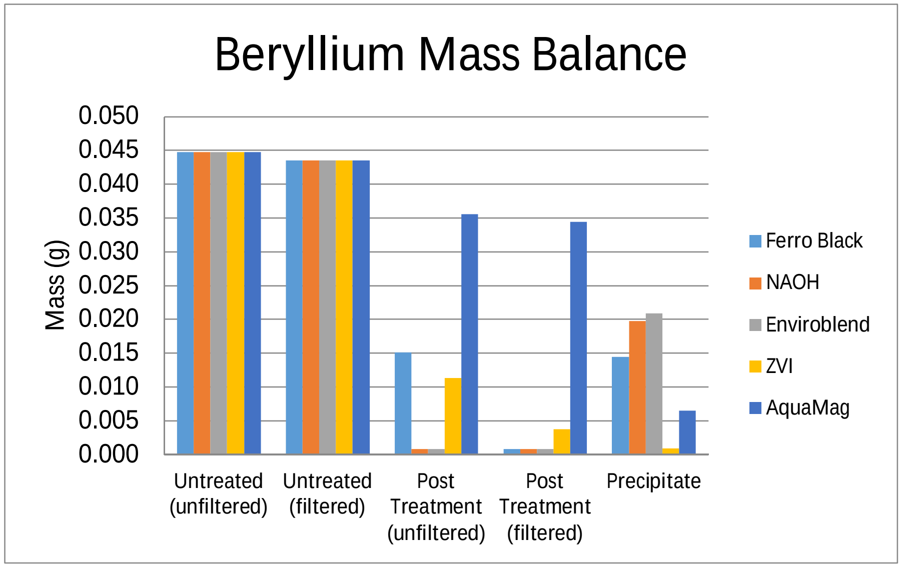
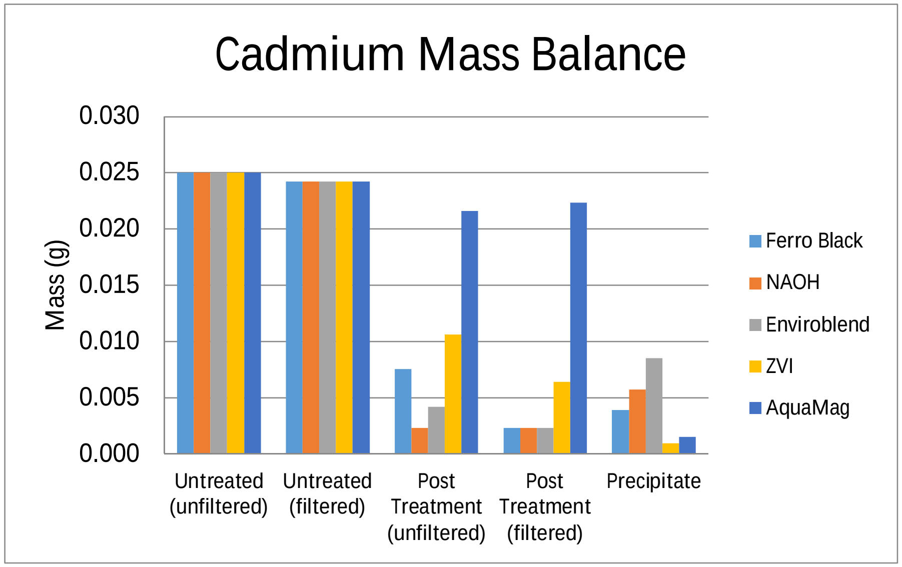
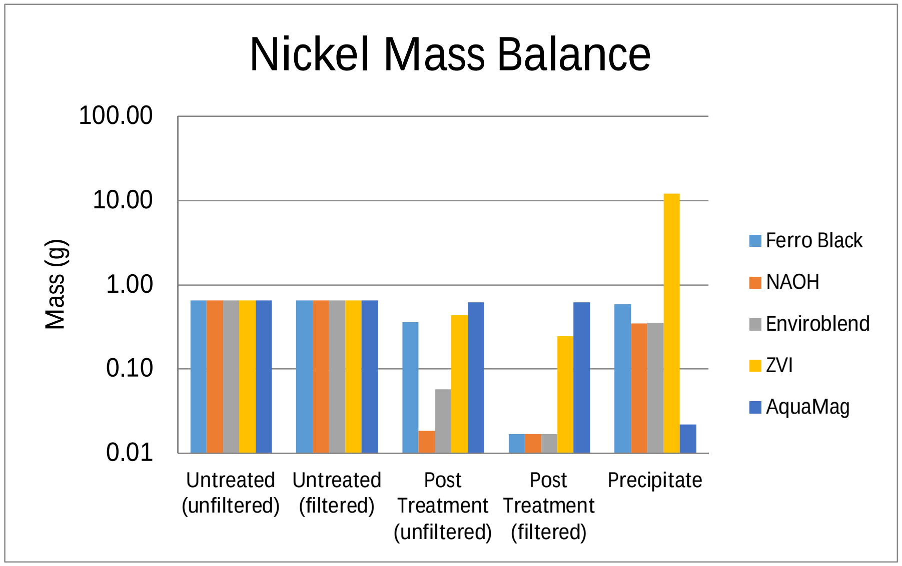
MORGAN	OSLUND	OSLUND	REV. 0

GALLATIN FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY

DATE:	DEPT:
08/24/2017	FOSSIL AND HYDRO ENGINEERING







AECOM

Figure 2

MASS BALANCE
METALS EXCEEDING MCLS

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DATE:	DEPT:
08/24/2017	FOSSIL AND HYDRO ENGINEERING

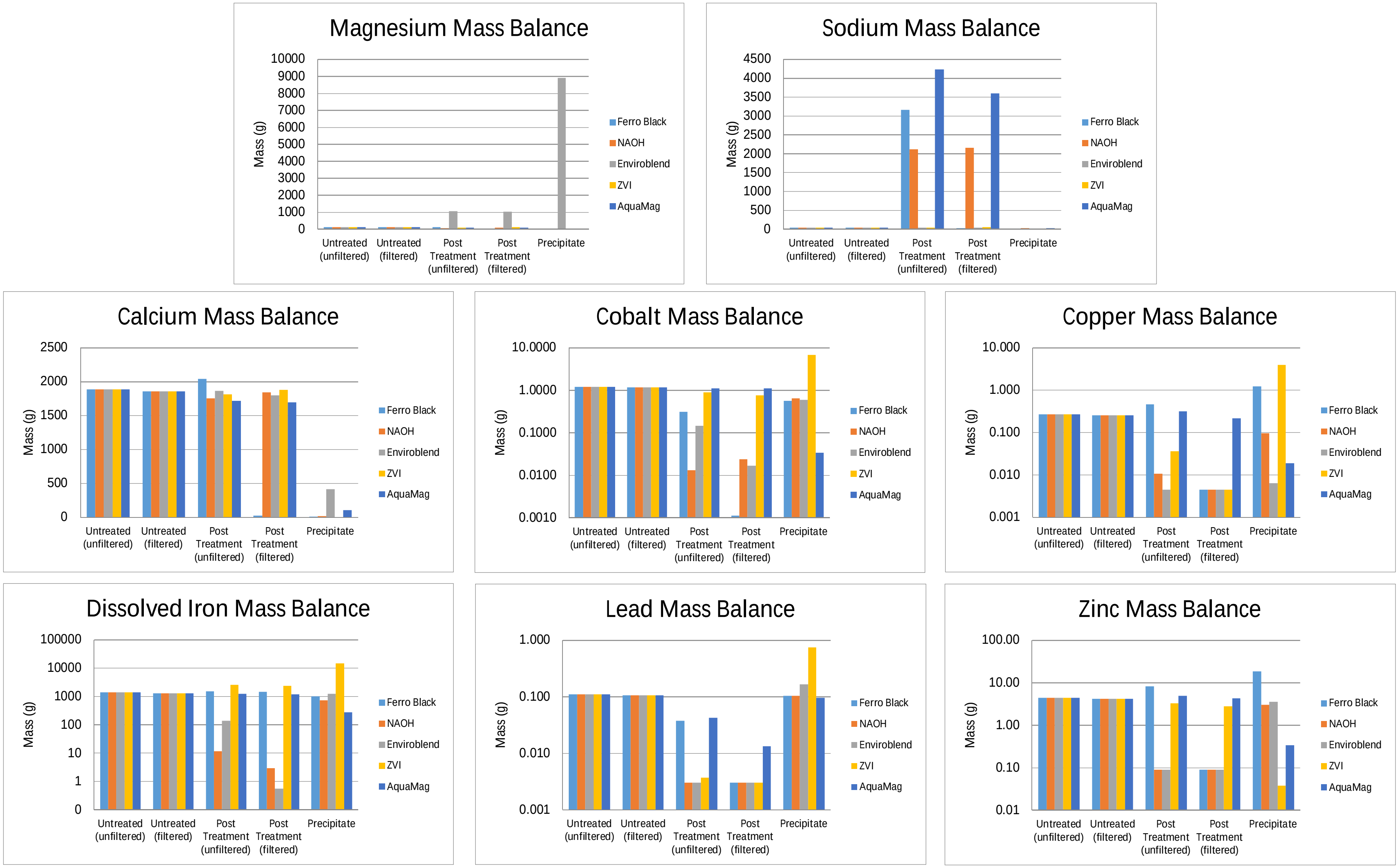

Figure 3

MASS BALANCE
NON-TARGET METALS

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GALLATIN FOSSIL PLANT
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DATE:	DEPT:
08/24/2017	FOSSIL AND HYDRO ENGINEERING

Attachment A

Attachment A
Well 19R Recent Data and MCL Comparison

Parameter	CCR GWPS[1] (mg/L)	TN Solid Waste Management GWPS[2] (mg/L)	NPDWR MCL[3] (mg/L)	February 2017 Unfiltered (mg/L)	February 2017 (Filtered) (mg/L)	March 2017 Unfiltered (mg/L)	March 2017 (Filtered) (mg/L)	April 2017 Unfiltered (mg/L)	April 2017 (Filtered) (mg/L)	May 2017 Unfiltered (mg/L)	May 2017 (Filtered) (mg/L)	June 2017 Unfiltered (mg/L)	June 2017 (Filtered) (mg/L)
Antimony	0.006	0.006	0.006	<0.00131	<0.000549	<0.000631	<0.000539	<0.00443	<0.00443	<0.000443	<0.000443	<0.00178	<0.00105
Arsenic	0.01	0.01	0.010	0.00330	0.00279	0.00221	0.00203	<0.00220	0.00244	0.0005	0.000434	0.0013	0.00105
Barium	2.0	2.0	2	0.0125	0.00974	<0.0113	0.0106	<0.0140	0.0185	0.0118	0.0114	0.0126	0.0123
Beryllium	0.004	0.004	0.004	**0.0102**	**0.00979**	**0.00838**	**0.00889**	**0.0113**	**0.0121**	**0.0116**	**0.0118**	**0.0116**	**0.0112**
Cadmium	0.005	0.005	0.005	0.00476	**0.00519**	**0.00703**	**0.00703**	**0.00654**	**0.00607**	**0.00827**	**0.00735**	**0.00656**	**0.00737**
Chromium	0.1 b	0.1^b	0.1^b	0.000882	0.000577	0.000791	0.000568	<0.00378	<0.00378	<0.000378	0.000389	0.000621	0.000603
Cobalt	Background	NA	NA	0.232	0.260	0.372	0.379	0.337	0.305	0.281	0.268	0.308	0.365
Copper	NA	NA	1.3	0.00966	0.0100	0.0144	0.0136	0.0147	0.0140	<0.0095	0.00908	0.0152	0.0193
Fluoride	4.0	4.0	4.0	0.199	---	0.244	---	0.274	---	0.227	---	0.289	---
Lead	0.015	0.015	0.015	0.00167	0.00151	0.00205	0.00188	<0.00318	<0.00318	0.00174	0.00167	0.00167	0.00812
Lithium	Background	NA	NA	0.110	0.104	0.0826	0.0867	<0.113	0.122	0.0952	0.0977	0.105	0.0996
Mercury	0.002	0.002	0.002	<0.0000521	<0.0000521	<0.000653	<0.0000653	<0.0000653	<0.0000653	<0.0000653	<0.0000653	<0.0000653	<0.0000653
Molybdenum	Background	NA	NA	0.00134	<0.000593	<0.000593	<0.000593	<0.00593	<0.00593	<0.000593	<0.000593	0.00116	<0.000593
Nickel	NA	0.1	NA	**0.135**	**0.144**	**0.189**	**0.194**	**0.178**	**0.165**	**0.128**	**0.125**	**0.162**	**0.182**
Selenium	0.05	0.05	0.05	0.0188	0.0202	0.0175	0.0179	0.0219	0.0135	0.00293	0.00232	0.00573	0.00724
Silver	NA	0.1	NA	<0.000200	<0.000200	<0.000200	<0.000200	<0.00200	<0.00200	<0.0002	<0.0002	<0.0002	<0.0002
Thallium	0.002	0.002	0.002	0.000920	0.000873	0.000950	0.00103	<0.000531	<0.000531	0.000978	0.00094	0.00115	0.00107
Vanadium	NA	NA	NA	0.0166	0.0145	0.0146	0.0146	<0.0162	0.0150	0.00989	0.0107	0.0138	0.0123
Zinc	NA	NA	NA	0.452	0.443	0.569	0.552	0.562	0.557	0.304	0.32	0.523	0.617
Radium 226+228	5 pCi/L	NA	5 pCi/L	2.00	2.02	2.07	2.35	2.21	2.37	Not Reported	2.11	Not Reported	Not Reported
Secondary Standards													
Aluminum	NA	NA	0.05 -0.2	**54.20**	**50.8**	**49.1**	**48.2**	**56.8**	**55.8**	**62.3**	**63.2**	**57.3**	**57**
Chloride	NA	NA	250	2.58	---	2.23	---	3.02	---	2.43	---	3.21	---
Iron	NA	NA	0.3	**417**	**384**	**390**	**388**	**395**	**402**	**279**	**304**	**396**	**367**
Manganese	NA	NA	0.05	**18.90**	**20.8**	**32.6**	**33.1**	**27.3**	**24.6**	**37.8**	**34.4**	**26.7**	**35.4**
pH	NA	NA	6.5-8.5	**3.81**	---	**3.75**	---	**3.72**	---	**3.68**	---	**3.47**	---
Sulfate	NA	NA	250	**2190**	---	**2180**	---	**2480**	---	**2250**	---	**2880**	---
TDS	NA	NA	500	**3500**	---	**3730**	---	**3630**	---	**3670**	---	**3720**	---
Zinc	NA	NA	5	0.452	0.443	0.569	0.552	0.562	0.557	0.304	0.32	0.523	0.617

Notes:

[1] - MCLs from CCR Regulations - Appendix I of Part 257 - Maximum Contaminant Levels

[2] - MCLs from Rules of Tennessee Department of Environmental and Conservation Solid Waste Management

[3] - MCLs from Nation Primary Drinking Water Regulations

[a] - MCL for hexavalent chromium

[b] - MCL for total chromium

Background - No MCL established, background concentration to be defined and used as groundwater protection standard

CCR - Coal Combustion Residuals

GWPS - Groundwater Protection Standard

MCL - Maximum Contamination Level

mg/L - milligram per liter

NA - Not Applicable/No MCL established

NPDWR - National Primary Drinking Water Reg

< - less than the indicated laboratory reporting limit

pCi/L - picocuries per liter

Dashes (---) - not result collected

Bold - exceedance of MCL or GWPS

Red shading - MCL or GWPS that is being exceeded

Not reported - Radium results from the April 2017 sampling event have not yet been reported

Attachment A
Well 19R Recent Data

	Units	18 Nov 2016	12 Dec 2016	13 Jan 2017	14 Feb 2017	15 Mar 2017	20 Apr 2017	17-May-17	13-Jun-17
Nitrogen, Kjeldahl, Total	MG/L	0.769	0.881	1.01	0.986	< 0.873	1.04	1.01	0.745
Nitrate-nitrite nitrogen	MG/L	< 0.0316	< 0.186	< 0.0316	< 0.0316	0.165	< 0.0316	< 0.0316	< 0.0316
Phosphorus	MG/L	< 0.0500	0.0510	< 0.0500	0.126	< 0.0500	0.0740	<0.05	<0.0677
Dissolved Oxygen	MG/L	0.11	0.38	0.3	0.55	0.36	0.28	0.78	0.29
ORP	MV	257.2	245.4	252.4	-16.5	260.8	258.1	266.8	265.7
pH, Field	pH SU	3.58	3.76	3.51	3.81	3.75	3.72	3.68	3.47
Temperature	deg c	17.28	15.67	15.51	15.21	15.3	16.8	17.4	17.5
Turbidity, field	NTU	15.1	14.9	13.4	11.2	13.8	10.2	12.8	15.2
Alkalinity, Total as CaCO3	MG/L	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00
Alkalinity,Bicarbonate (CaCO3)	MG/L	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00
Alkalinity, Carbonate (CaCO3)	MG/L	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00
Total Dissolved Solids	MG/L	3760	3760	3800	3500	3730	3630	3670	3720
Total Suspended Solids	MG/L	11.7	11.4	6.80	7.80	6.00	6.00	7.6	8.5
Total Organic Carbon	MG/L	< 0.604	< 0.495	< 0.967	0.896	< 0.673	< 0.508	0.566	<0.508
Sulfate	MG/L	2210	2180	2390	2190	2180	2480	2250	2880

Attachment B

REDOX TECH, LLC
"Providing Innovative In Situ Soil and Groundwater Treatment"

August 11, 2017

Via email
Barbara Oslund
AECOM
1600 Perimeter Park Drive
Suite 400
Morrisville, NC 27560
PH: (919) 461-1470
Barbara.oslund@aecom.com

RE: Bench Scale Testing Coal Ash Groundwater Samples Letter Report

Dear Ms. Oslund,

The following report presents the findings and recommendations from the Bench Screening Tests that were conducted on groundwater samples associated with coal ash delivered to our office in Cary, NC on July 12, 2017.

EXECUTIVE SUMMARY

On July 12, 2017 Redox Tech received groundwater samples collected by AECOM from an acidic groundwater source, presumably impacted by coal ash. The principal analytes of concern were beryllium (Be), cadmium (Cd), and nickel (Ni) although a much larger suite of chemicals were tested. The samples were homogenized and treated in batch studies with 5 different amendments over a period of approximately 2 days. The treated samples and controls were sent to Pace Analytical for analyses based on the requirements provided by AECOM. Filtered and unfiltered groundwater, and solid precipitates (as appropriate) were analyzed. The goal of this project was to determine if the application of any of the amendments caused a change in the groundwater chemistry. This test was not designed to quantify the amendment dosing requirements for a specific analyte or resulting concentration target in groundwater.

The five amendments used in the treatability/screening test were AQUAMAG® (Carus Corp.); EnviroBlend® (Premier Magnesia, LLC.); FerroBlack® (RedoxSolutions also called Redox Technology Group, LLC was formed several years after and should not be confused with Redox Tech, LLC); zero valent iron (Redox Tech, LLC); and sodium hydroxide (25 wt% solution received from Brenntag Southeast, Inc.). The statement of work for this project required testing both filtered and unfiltered samples so two 1-gallon reactor vessels were needed for each amendment. A control consisting of groundwater with no amendments added was also dispensed into two separate treatment reactor vessels.

Results from these tests indicate that all of the tested amendments produced some measureable effect on the contaminants of concern. At the specific dosing for this screening test, three of the amendments were able to reduce concentrations of the targeted constituents (Be, Cd, and Ni) more than the others. However, an optimized dosing scheme for each of the amendments may potentially enable each of the amendments to satisfactorily reduce the target constituents. Depending on additional considerations (e.g., cost, amount of precipitate produced, ease of use, etc.), a particular amendment may emerge as a better choice for application in the field than the others. We recommend more focused treatability testing to achieve the specific goals for the site.

SAMPLE COLLECTION

On July 12, 2017, groundwater samples were received by Redox Tech, LLC in Cary, NC. These samples were collected by AECOM personnel and shipped overnight to Redox Tech. The samples consisted of five 5-gallon plastic containers (total of approximately 25 gallons of groundwater) that were previously used to hold distilled water. The containers were kept in coolers until testing began on July 18, 2017. The groundwater as received in each of the containers had slightly different colors (Fig. 1) so the samples were homogenized in a clean (pressure-washed) 30-gallon plastic container and re-circulated using a pump. The homogenized groundwater was then dispensed to fourteen clean, 1-gallon plastic containers (formerly containing distilled water) for treatability/screening testing. Five amendments were tested: AQUAMAG**®**; EnviroBlend®; FerroBlack®, Sodium hydroxide (NaOH); and Zero Valent Iron (zvi).

Figure 1. Groundwater as received.

AMENDMENT DESCRIPTION

AQUAMAG is a blended phosphate product designed to prohibit corrosion of metals (see attached data sheet, http://www.caruscorporation.com/page/water/products/aquamag). EnviroBlend is a custom-made magnesium based slurry designed to regulate pH and precipitate metals (https://www.enviroblend.com) . FerroBlack is a custom-made sulfide based amendment designed for treatment of heavy metal impacted groundwater (http://www.redoxsolutions.com/Home_Page.html) . The zero valent iron used in these experiments for pH adjustment, co-precipitation and sorption is produced under hydrogen reducing conditions and ranges in size from approximately 40 to 180 micometers (https://www.redox-tech.com/zvi/) . The sodium hydroxide solution used in these experiments is technical grade caustic soda at a concentration of 25 wt% in water (density = 1.27 g/mL) and is used to raise the pH of the acidic groundwater. All of the amendments except for sodium hydroxide were dosed in groundwater at approximately 10 g amendment per liter of groundwater. The 25 wt% sodium hydroxide solution was added at approximately 3.3 g amendment per liter of groundwater.

TEST PROCEDURES

Batch Reactor Preparation

Each 1-gallon reactor vessel received groundwater from the 30-gallon tank containing the homogenized groundwater. Two 1-gallon reactor vessels were required for each amendment as well as the control due to the requirement of a filtered and unfiltered sample, and the analytical requirements for mass and volume of sample. To complete the required analyses, each sample was split into 7 sample containers (Table 1).

Table 1. Analytical requirements per sample

Analytical Requirements			
Method	Size (mL)	No. of Bottles	Analysis
160.4, 2320B, 2540C, 4500H+B	1000	2	Alkalinity, TDS, TS
300.0, 9056	250	1	Chloride, fluoride
6020	250	1	Total Metals
160.4	125	1	ignitability
4500S2D	125	1	sulfide
365.1	125	1	Total Phosphorous

Treatability Testing

A total of twelve 1-gallon reactors were used to conduct the bench treatability/screening test. The treatability/screening test was performed with site groundwater samples dosed according to Table 2. The samples were mixed by vigorously inverting the reactor vessel for approximately 30 seconds, twice per day. It is likely that a significant portion of the reactions for each amendment occurred in the first few hours but we let the reactions proceed for at least 48 hours to allow contact by both advection and diffusion. The samples were then transferred to the appropriate analytical bottles and delivered to Pace Analytical in Raleigh, NC. All samples with an F suffix (e.g., CONTF2) indicate that the sample was filtered before being transferred to the analytical bottles. Filtering was performed using a vacuum filtration system and 0.45 micron filter. Depending on the apparent particle size and amount of precipitate and other suspended solids in the reactor vessel, filtering took up to 3 hours.

All filtered solids were collected in 4-oz amber glass jars and delivered to Pace Analytical for analysis if appropriate. The mass of solids collected varied from 3.4 g from the AQUAMAG treatment vessel to 34.4 g from the ZVI treatment vessel and are listed in Table 3. The solids were collected from the filters after being allowed to dry in a fume hood for up to 5 days.

Table 2. List of treatments and doses

Amendment	pH (pre-dose)	Dose (g)	pH (post-dose)	pH 1 Day	pH 2 Day	Reactor Time (hrs)
Control (CONT1)	3.75	0		3.41	3.14	66
AQUAMAG (AM1)	3.8	40.9	3.85	3.65	3.55	67
AQUAMAG (AMF2)	3.85	38.9	3.85	3.64	3.52	70
EnviroBlend (EB1)	3.75	39.8	5.8	7	7.23	67
EnviroBlend (EBF2)	3.74	39.8	6	7.2	7.37	70
FerroBlack (FB1)	3.75	38.6	5.2	5.69	5.81	67
FerroBlack (FBF2)	3.75	38.9	4.9	5.4	5.76	138
Zvi (ZVI1)	3.73	38.0	4.17	4.6	4.84	67
Zvi (ZVIF2)	3.74	38.5	3.88	4.64	4.88	143
NaOH (NaOH1)	3.58	12.7	8.5	8.37	7.85	67
NaOH (NaOHF2)	3.58	12.7	8.34	8.25	7.68	140
Control (CONTF2)	3.63	0		3.41	3.15	69

Table 3. Solids collected from filters

Treatment	Mass Collected (g)
FerroBlack (FBS)	5.8
NaOH (NaOHS)	10.4
Enviro Blend (EBS)	29.4
ZVI (ZVIS)	34.4
AQUAMAG (AMS)	3.4

TEST RESULTS

Treatability testing indicates that all of the amendments were successful in reducing concentrations of some of the analytes, particularly after the treated groundwater was filtered. The greatest reduction in concentrations of analytes was achieved by treatment with Enviroblend (both filtered and unfiltered), FerroBlack (filtered), and simple sodium hydroxide addition (both filtered and unfiltered). These treatment regimes reduced the concentrations of the following analytes by more than an order of magnitude: Aluminum, Arsenic, Beryllium, Cadmium, Cobalt, Copper, Iron, Lead, Nickel, Selenium, and Zinc. In addition, the FerroBlack filtered treatment removed lithium and manganese. The filtered zvi treatment was effective at significantly reducing concentrations of Aluminum, Beryllium, Cadmium, Copper, Lead, Nickel, and Selenium. The AquaMag treatment showed some reduction in several of the analytes (Aluminum, Barium, Beryllium, Iron, Manganese, Nickel, and Selenium) but may have been underdosed for treating this groundwater. Several of the treatments resulted in increases in concentration of some of the analytes for example, the magnesium-based EnviroBlend resulted in an order of magnitude increase in magnesium, while the FerroBlack and zvi treatments resulted in increases of dissolved iron concentrations. In addition, increases in sodium concentration were observed in the sodium hydroxide treatment.

Although varying amounts of solids were recovered from filtration, even the largest amounts recovered (EnviroBlend and zvi treatments) were small (less than 1 wt%) relative to the amount of groundwater treated. If these amendments are used in a groundwater soil matrix they are unlikely to create pore-clogging issues, however we strongly recommend pilot scale testing to confirm.

A matrix of the analytical results is provided as Appendix A in an attached spreadsheet file entitled AECOM Coal Ash Results.xlsx. Photos of the reactor vessels in comparison with the control reactors post treatment is provided in Appendix B and the full laboratory reports are provided in three attached files as Appendix C.

CONCLUSIONS / RECOMMENDATIONS

The treatability testing indicates that the principal target compounds (Be, Cd, Ni) in the groundwater samples were effectively treated by three of the testing regimes at the pre-selected dose but were also positively affected by the other two regimes. It is possible that the other two treatment regimes may perform better at a different dose. The simplest and likely least costly treatment, adjusting the pH using sodium hydroxide, performed very well on the target compounds as well as several others. If the groundwater will be treated independently of the soil matrix there appear to be several possibilities for effective treatment but to select the best method it will be necessary to understand the engineering constraints and goals before starting additional tests to determine amendment, method, and dose.

Finally, this initial screening test is not sufficient to determine an amendment's effectiveness at treating the targeted groundwater analytes in a soil matrix (in situ). We strongly recommend tests using both soil and groundwater to determine prior to decisions about field application of these or other amendments.

Please don't hesitate to contact me if you have any questions about this letter report.

Sincerely,

Joe Rossabi, Ph.D., P.E.
Redox Tech, LLC

Appendix A

Summary of Analytical Results File.

1. AECOM Coal Ash Results.xlsx Groundwater and solids analytical results.

AECOM Coal Ash Treatability Results

Effect	Reduction in concentration	
🟥	strong	> 10X
🟨	medium	> 2X
🟩	some	

🟦 Increase in concentration

Groundwater

			AQUAMAG		EnviroBlend		FerroBlack		Base		Zero Valent Iron	
	Cont1	ContF2	AM1	AMF2	EB1	EBF2	FB1	FBF2	NaOH1	NaOHF2	ZVI1	ZVIF2
	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)
Aluminum	61,700	59,900	39,900	34,800	340	ND	49,500	69.6J	526	77.8J	5,870	451
Antimony	ND	ND	1.0J	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	2.3	2.1	3.4	3	ND	ND	1.8	ND	ND	ND	1.3	0.77J
Barium	19	18.9	6.7	4.2	23.1	20.8	22.1	57.2	12.2	9.9	17.2	20.7
Beryllium	11.8	11.5	9.4	9.1	ND	ND	4	0.22J	ND	ND	3	1
Cadmium	6.6	6.4	5.7	5.9	1.1	ND	2	ND	ND	ND	2.8	1.7
Calcium	499,000	491,000	454,000	448,000	493,000	475,000	540,000	5,610	464,000	486,000	480,000	496,000
Chromium	ND	ND	2.1J	2.2J	ND	1.2J	92.6	1.3J	ND	1.2J	6.5	ND
Cobalt	321	312	295	295	38.8	4.4	84	0.29J	3.5	6.3	239	200
Copper	70.6	66.6	84.4	58.1	ND	ND	123	ND	2.8J	ND	9.7	ND
Iron	363,000	343,000	328,000	311,000	36,500	138J	593,000	ND	3,060	762	669,000	622,000
Lead	29.2	28	11.2	3.5	ND	ND	10	ND	ND	ND	0.98J	ND
Lithium	117	113	113	113	118	117	61.2	13.5J	109	99	108	107
Magnesium	28,200	27,900	26,100	26,300	281,000	272,000	29,300	3,780	18,700	23,200	27,000	28,200
Manganese	27,300	27,600	25,500	22,700	15,500	8,560	31,700	12	4,220	8,470	28,300	28,300
Molybdenum	ND	ND	12.6	10.7	ND	ND	14	ND	ND	ND	ND	ND
Nickel	172	171	164	164	15	ND	95.7	ND	4.9J	ND	116	65.2
Potassium	15,700	15,100	14,700	14,200	15,900	14,900	17,400	2,640	15,000	15,100	14,600	16,900
Selenium	26.5	25.9	21.1	19	ND	ND	12.8	ND	ND	ND	13.8	10.2
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sodium	10,400	10,400	1,120,000	953,000	11,100	11,300	837,000	7,540	558,000	572,000	10,700	12,600
Thallium	1.1	0.96J	0.50J	0.45J	0.87J	0.75J	0.27J	ND	0.74J	0.72J	ND	ND
Vanadium	ND	ND	10.4	9.6	ND	ND	17.9	3.5J	ND	ND	8.9	ND
Zinc	1180	1130	1310	1160	ND	ND	2180	ND	ND	ND	885	745
Dissolved Iron	370,000	347,000	233,000	231,000	2040	1,400	403,000	387,000	17,100	ND	613,000	579,000
sulfide (mg/L)	ND	ND	ND	ND	ND	ND	15.7	0.88	ND	ND	0.21	ND
sulfate (mg/L)	2230	2400	2200	2070	2140	2090	2270	2740	2170	2550	2140	2350
phosphorous (mg/L)	.032J	.031J	857	827	.032J	0.16	0.065	.031J	.029J	ND	0.055	.044J
chloride (mg/L)	2.9	2.9	4.3	4.7	5.3	5.8	755	804	3.1	4.3	2.9	4.2
fluoride (mg/L)	0.4	0.37	0.26	0.22	0.11	.099J	ND	ND	0.29	0.24	0.18	0.18
Total Solids (mg/L)	3760	3920	6650	7190	4440	3660	6750	980	5620	727	3980	1920
Total Volatile Solids (mg/L)	700	630	140	950	748	620	1410	132	615	54	795	250
Total Dissolved Solids (mg/L)	3390	3200	5280	5730	3310	2960	4540	4620	3530	3450	3680	3690
pH	3	3	3.1	3.2	7.9	7.6	6	4.3	7.5	7.5	5.5	3.7
alkalinity bicarb (mg/L)	ND	ND	ND	ND	4.9J	17.5	ND	ND	454		ND	ND
alkalinity carb (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND
alkalinity total (mg/L)	ND	ND	ND	ND	4.9J	17.5	ND	ND	454	48.1	ND	ND
Amount of solids collected (g):				3.4		29.4		5.8		10.4		34.4

Solid Precipitate

	AQUAMAG	EnviroBlend	FerroBlack	NaOH	ZVI
Amt of precipitate collected:	3.40 g	29.38 g	5.79 g	10.41 g	34.37 g
	Conc (mg/kg)	Conc (mg/kg)	Conc (mg/kg)	Conc (mg/kg)	Conc (mg/kg)
Aluminum	17,700	5,540	50,000	10,500	1,270
Antimony	ND	ND	ND	ND	10.6
Arsenic	8.7J	5.3	8.9J	7.7J	9.9
Barium	13.5	1.6	ND	ND	ND
Beryllium	1.9	0.71	2.5	1.9	ND
Cadmium	ND	0.29	ND	ND	ND
Calcium	30,600	14,200	1,510	1,680	116
Chromium	3.7J	3.2	97.1	ND	43.8
Cobalt	9.9	20.6	98.5	61.7	199
Copper	5.6	ND	211	9.3	114
Iron	82,300	41,800	173,000	69,900	434,000
Lead	28.2	5.7	18	10.1	21.8
Magnesium	857	303,000	186	534	ND
Manganese	2,780	2,000	499	3,140	37.4
Molybdenum	2.9J	2.3	21.2	ND	8.9
Nickel	6.4	12.1	101	33	350
Potassium	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND
Silver	ND	0.24J	ND	ND	2.7
Sodium	7,170	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	1.2
Vanadium	6.3	5.8	18.3	3.5J	61.0
Zinc	99.6	121.0	3,180	288	1.1

Appendix B

Photos of reactor vessels post treatment.

Figure A-1. Control and AQUAMAG post treatment

Figure A-2. Control and EnviroBlend post treatment

Figure A-3. Control and FerroBlack post treatment

Figure A-4. Control and NaOH post treatment.

Figure A-5. Control and zvi post treatment.

Appendix C

Laboratory Report Files

1. Coal Ash 92348734_frc.pdf	Groundwater: Unfiltered and Filtered
2. Coal Ash 92348882_frc.pdf	Groundwater: Filtered
3. Coal Ash 92349301_frc.pdf	Precipitates and solids

Pace Analytical Services, LLC
9800 Kincey Ave. Suite 100
Huntersville, NC 28078
(704)875-9092

August 02, 2017

Joe Rassabi

200 Quade Drive
Cary, NC 27513

RE: Project: COAL ASH
Pace Project No.: 92348734

Dear Joe Rassabi:

Enclosed are the analytical results for sample(s) received by the laboratory on July 24, 2017. The results relate only to the samples included in this report. Results reported herein conform to the most current, applicable TNI/NELAC standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Taylor Ezell
taylor.ezell@pacelabs.com
(704)875-9092
Project Manager

Enclosures

cc: John Haselow, Redox Tech, LLC

CERTIFICATIONS

Project:	COAL ASH
Pace Project No.:	92348734

Asheville Certification IDs

2225 Riverside Drive, Asheville, NC 28804
Florida/NELAP Certification #: E87648
Massachusetts Certification #: M-NC030
North Carolina Drinking Water Certification #: 37712
North Carolina Wastewater Certification #: 40
South Carolina Certification #: 99030001
Virginia/VELAP Certification #: 460222

SAMPLE SUMMARY

Project: COAL ASH
Pace Project No.: 92348734

Lab ID	Sample ID	Matrix	Date Collected	Date Received
92348734001	**CONT 1**	Water	07/21/17 09:39	07/24/17 12:11
92348734002	**AM 1**	Water	07/21/17 10:09	07/24/17 12:11
92348734003	**EB 1**	Water	07/21/17 10:17	07/24/17 12:11
92348734004	**FB 1**	Water	07/21/17 10:33	07/24/17 12:11
92348734005	**NAOH 1**	Water	07/21/17 10:42	07/24/17 12:11
92348734006	**ZVI 1**	Water	07/21/17 10:39	07/24/17 12:11
92348734007	**CONT F2**	Water	07/21/17 11:55	07/24/17 12:11
92348734008	**AMF 2**	Water	07/21/17 13:13	07/24/17 12:11
92348734009	**EBF 2**	Water	07/21/17 14:39	07/24/17 12:11

SAMPLE ANALYTE COUNT

Project: COAL ASH
Pace Project No.: 92348734

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
92348734001	**CONT 1**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	3	PASI-A
		SM 2540C	SLB	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	MVC	1	PASI-A
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	AES2	1	PASI-A
		EPA 9056A	CDC	2	PASI-A
92348734002	**AM 1**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	3	PASI-A
		SM 2540C	SLB	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	MVC	1	PASI-A
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	AES2	1	PASI-A
		EPA 9056A	CDC	2	PASI-A
92348734003	**EB 1**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	3	PASI-A
		SM 2540C	SLB	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	MVC	1	PASI-A
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	AES2	1	PASI-A
		EPA 9056A	CDC	2	PASI-A
92348734004	**FB 1**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	3	PASI-A
		SM 2540C	SLB	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	MVC	1	PASI-A

SAMPLE ANALYTE COUNT

Project: COAL ASH
Pace Project No.: 92348734

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	AES2	1	PASI-A
		EPA 9056A	CDC	2	PASI-A
92348734005	**NAOH 1**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	3	PASI-A
		SM 2540C	NAL	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	MVC	1	PASI-A
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	AES2	1	PASI-A
		EPA 9056A	CDC	2	PASI-A
92348734006	**ZVI 1**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	3	PASI-A
		SM 2540C	SLB	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	MVC	1	PASI-A
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	AES2	1	PASI-A
		EPA 9056A	CDC	2	PASI-A
92348734007	**CONT F2**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	3	PASI-A
		SM 2540C	SLB	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	MVC	1	PASI-A
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	AES2	1	PASI-A
		EPA 9056A	CDC	2	PASI-A
92348734008	**AMF 2**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	3	PASI-A

SAMPLE ANALYTE COUNT

Project: COAL ASH
Pace Project No.: 92348734

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
		SM 2540C	SLB	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	MVC	1	PASI-A
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	AES2	1	PASI-A
		EPA 9056A	CDC	2	PASI-A
92348734009	**EBF 2**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	3	PASI-A
		SM 2540C	SLB	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	MVC	1	PASI-A
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	AES2	1	PASI-A
		EPA 9056A	CDC	2	PASI-A

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: CONT 1 **Lab ID: 92348734001** Collected: 07/21/17 09:39 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	**61700**	ug/L	100	67.0	10	07/26/17 04:45	07/28/17 16:19	7429-90-5	D3
Antimony	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:19	7440-36-0	D3
Arsenic	**2.3**	ug/L	1.0	0.50	10	07/26/17 04:45	07/28/17 16:19	7440-38-2	D3
Barium	**19.0**	ug/L	3.0	1.1	10	07/26/17 04:45	07/28/17 16:19	7440-39-3	D3
Beryllium	**11.8**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:19	7440-41-7	D3
Cadmium	**6.6**	ug/L	0.80	0.60	10	07/26/17 04:45	07/28/17 16:19	7440-43-9	D3
Calcium	**499000**	ug/L	20000	10300	100	07/26/17 04:45	07/31/17 12:59	7440-70-2	D3
Chromium	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:19	7440-47-3	D3
Cobalt	**321**	ug/L	1.0	0.10	10	07/26/17 04:45	07/28/17 16:19	7440-48-4	D3
Copper	**70.6**	ug/L	5.0	1.2	10	07/26/17 04:45	07/28/17 16:19	7440-50-8	D3
Iron	**363000**	ug/L	500	118	10	07/26/17 04:45	07/28/17 16:19	7439-89-6	D3
Lead	**29.2**	ug/L	1.0	0.80	10	07/26/17 04:45	07/28/17 16:19	7439-92-1	D3
Lithium	**117**	ug/L	25.0	0.70	10	07/26/17 04:45	07/28/17 16:19	7439-93-2	D3
Magnesium	**28200**	ug/L	100	17.0	10	07/26/17 04:45	07/28/17 16:19	7439-95-4	D3
Manganese	**27300**	ug/L	50.0	19.0	100	07/26/17 04:45	07/31/17 12:59	7439-96-5	D3
Molybdenum	ND	ug/L	5.0	1.1	10	07/26/17 04:45	07/28/17 16:19	7439-98-7	D3
Nickel	**172**	ug/L	5.0	4.5	10	07/26/17 04:45	07/28/17 16:19	7440-02-0	D3
Potassium	**15700**	ug/L	500	258	10	07/26/17 04:45	07/28/17 16:19	7440-09-7	D3
Selenium	**26.5**	ug/L	5.0	3.2	10	07/26/17 04:45	07/28/17 16:19	7782-49-2	D3
Silver	ND	ug/L	5.0	0.80	10	07/26/17 04:45	07/28/17 16:19	7440-22-4	D3
Sodium	**10400**	ug/L	2500	129	10	07/26/17 04:45	07/28/17 16:19	7440-23-5	D3
Thallium	**1.1**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:19	7440-28-0	D3
Vanadium	ND	ug/L	5.0	0.70	10	07/26/17 04:45	07/28/17 16:19	7440-62-2	D3
Zinc	**1180**	ug/L	50.0	24.0	10	07/26/17 04:45	07/28/17 16:19	7440-66-6	D3
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	**370000**	ug/L	500	118	10	07/27/17 03:10	07/28/17 18:15	7439-89-6	M6
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**3760**	mg/L	12.5	12.5	1		07/26/17 00:15		
Total Volatile Solids	**700**	mg/L	12.5	12.5	1		07/26/17 00:15		D6
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/27/17 23:16		
Alkalinity, Carbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/27/17 23:16		
Alkalinity, Total as CaCO3	ND	mg/L	5.0	1.0	1		07/27/17 23:16		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**3390**	mg/L	50.0	50.0	1		07/27/17 10:56		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**3.0**	Std. Units	1.0	0.10	1		07/28/17 11:37		E,H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	ND	mg/L	0.10	0.10	1		07/25/17 19:00	18496-25-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: CONT 1 **Lab ID: 92348734001** Collected: 07/21/17 09:39 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2230**	mg/L	46.0	23.0	46		07/26/17 17:30	14808-79-8	M6
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	**0.032J**	mg/L	0.050	0.025	1		07/26/17 12:48	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**2.9**	mg/L	1.0	0.50	1		07/29/17 19:38	16887-00-6	
Fluoride	**0.40**	mg/L	0.10	0.050	1		07/29/17 19:38	16984-48-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: AM 1 **Lab ID: 92348734002** Collected: 07/21/17 10:09 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	**39900**	ug/L	100	67.0	10	07/26/17 04:45	07/28/17 16:21	7429-90-5	D3
Antimony	**1.0J**	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:21	7440-36-0	D3
Arsenic	**3.4**	ug/L	1.0	0.50	10	07/26/17 04:45	07/28/17 16:21	7440-38-2	D3
Barium	**6.7**	ug/L	3.0	1.1	10	07/26/17 04:45	07/28/17 16:21	7440-39-3	D3
Beryllium	**9.4**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:21	7440-41-7	D3
Cadmium	**5.7**	ug/L	0.80	0.60	10	07/26/17 04:45	07/28/17 16:21	7440-43-9	D3
Calcium	**454000**	ug/L	2000	1030	10	07/26/17 04:45	07/28/17 16:21	7440-70-2	D3
Chromium	**2.1J**	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:21	7440-47-3	D3
Cobalt	**295**	ug/L	1.0	0.10	10	07/26/17 04:45	07/28/17 16:21	7440-48-4	D3
Copper	**84.4**	ug/L	5.0	1.2	10	07/26/17 04:45	07/28/17 16:21	7440-50-8	D3
Iron	**328000**	ug/L	500	118	10	07/26/17 04:45	07/28/17 16:21	7439-89-6	D3
Lead	**11.2**	ug/L	1.0	0.80	10	07/26/17 04:45	07/28/17 16:21	7439-92-1	D3
Lithium	**113**	ug/L	25.0	0.70	10	07/26/17 04:45	07/28/17 16:21	7439-93-2	D3
Magnesium	**26100**	ug/L	100	17.0	10	07/26/17 04:45	07/28/17 16:21	7439-95-4	D3
Manganese	**25500**	ug/L	50.0	19.0	100	07/26/17 04:45	07/31/17 13:01	7439-96-5	D3
Molybdenum	**12.6**	ug/L	5.0	1.1	10	07/26/17 04:45	07/28/17 16:21	7439-98-7	D3
Nickel	**164**	ug/L	5.0	4.5	10	07/26/17 04:45	07/28/17 16:21	7440-02-0	D3
Potassium	**14700**	ug/L	500	258	10	07/26/17 04:45	07/28/17 16:21	7440-09-7	D3
Selenium	**21.1**	ug/L	5.0	3.2	10	07/26/17 04:45	07/28/17 16:21	7782-49-2	D3
Silver	ND	ug/L	5.0	0.80	10	07/26/17 04:45	07/28/17 16:21	7440-22-4	D3
Sodium	**1120000**	ug/L	25000	1290	100	07/26/17 04:45	07/31/17 13:01	7440-23-5	D3
Thallium	**0.50J**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:21	7440-28-0	D3
Vanadium	**10.4**	ug/L	5.0	0.70	10	07/26/17 04:45	07/28/17 16:21	7440-62-2	D3
Zinc	**1310**	ug/L	50.0	24.0	10	07/26/17 04:45	07/28/17 16:21	7440-66-6	D3
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	**233000**	ug/L	500	118	10	07/27/17 03:10	07/28/17 18:21	7439-89-6	
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**6650**	mg/L	25.0	25.0	1		07/26/17 00:15		
Total Volatile Solids	**140**	mg/L	25.0	25.0	1		07/26/17 00:15		
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/27/17 23:23		
Alkalinity, Carbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/27/17 23:23		
Alkalinity, Total as CaCO3	ND	mg/L	5.0	1.0	1		07/27/17 23:23		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**5280**	mg/L	250	250	1		07/27/17 10:57		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**3.1**	Std. Units	1.0	0.10	1		07/28/17 11:37		E,H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	ND	mg/L	0.10	0.10	1		07/25/17 19:00	18496-25-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: AM 1 **Lab ID: 92348734002** Collected: 07/21/17 10:09 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2200**	mg/L	100	50.0	100		07/26/17 19:30	14808-79-8	
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	**857**	mg/L	25.0	12.5	500		07/26/17 13:23	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**4.3**	mg/L	1.0	0.50	1		07/29/17 20:27	16887-00-6	
Fluoride	**0.26**	mg/L	0.10	0.050	1		07/29/17 20:27	16984-48-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: EB 1 **Lab ID: 92348734003** Collected: 07/21/17 10:17 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	**340**	ug/L	100	67.0	10	07/26/17 04:45	07/28/17 16:23	7429-90-5	D3
Antimony	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:23	7440-36-0	D3
Arsenic	ND	ug/L	1.0	0.50	10	07/26/17 04:45	07/28/17 16:23	7440-38-2	D3
Barium	**23.1**	ug/L	3.0	1.1	10	07/26/17 04:45	07/28/17 16:23	7440-39-3	D3
Beryllium	ND	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:23	7440-41-7	D3
Cadmium	**1.1**	ug/L	0.80	0.60	10	07/26/17 04:45	07/28/17 16:23	7440-43-9	D3
Calcium	**493000**	ug/L	20000	10300	100	07/26/17 04:45	07/31/17 13:03	7440-70-2	D3
Chromium	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:23	7440-47-3	D3
Cobalt	**38.8**	ug/L	1.0	0.10	10	07/26/17 04:45	07/28/17 16:23	7440-48-4	D3
Copper	ND	ug/L	5.0	1.2	10	07/26/17 04:45	07/28/17 16:23	7440-50-8	D3
Iron	**36500**	ug/L	500	118	10	07/26/17 04:45	07/28/17 16:23	7439-89-6	D3
Lead	ND	ug/L	1.0	0.80	10	07/26/17 04:45	07/28/17 16:23	7439-92-1	D3
Lithium	**118**	ug/L	25.0	0.70	10	07/26/17 04:45	07/28/17 16:23	7439-93-2	D3
Magnesium	**281000**	ug/L	100	17.0	10	07/26/17 04:45	07/28/17 16:23	7439-95-4	D3
Manganese	**15500**	ug/L	50.0	19.0	100	07/26/17 04:45	07/31/17 13:03	7439-96-5	D3
Molybdenum	ND	ug/L	5.0	1.1	10	07/26/17 04:45	07/28/17 16:23	7439-98-7	D3
Nickel	**15.0**	ug/L	5.0	4.5	10	07/26/17 04:45	07/28/17 16:23	7440-02-0	D3
Potassium	**15900**	ug/L	500	258	10	07/26/17 04:45	07/28/17 16:23	7440-09-7	D3
Selenium	ND	ug/L	5.0	3.2	10	07/26/17 04:45	07/28/17 16:23	7782-49-2	D3
Silver	ND	ug/L	5.0	0.80	10	07/26/17 04:45	07/28/17 16:23	7440-22-4	D3
Sodium	**11100**	ug/L	2500	129	10	07/26/17 04:45	07/28/17 16:23	7440-23-5	D3
Thallium	**0.87J**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:23	7440-28-0	D3
Vanadium	ND	ug/L	5.0	0.70	10	07/26/17 04:45	07/28/17 16:23	7440-62-2	D3
Zinc	ND	ug/L	50.0	24.0	10	07/26/17 04:45	07/28/17 16:23	7440-66-6	D3
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	**2040**	ug/L	500	118	10	07/27/17 03:10	07/28/17 18:23	7439-89-6	
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**4440**	mg/L	5.0	5.0	1		07/26/17 00:15		
Total Volatile Solids	**748**	mg/L	5.0	5.0	1		07/26/17 00:15		
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	**4.9J**	mg/L	5.0	1.0	1		07/27/17 23:29		
Alkalinity, Carbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/27/17 23:29		
Alkalinity, Total as CaCO3	**4.9J**	mg/L	5.0	1.0	1		07/27/17 23:29		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**3310**	mg/L	50.0	50.0	1		07/27/17 10:57		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**7.9**	Std. Units	1.0	0.10	1		07/28/17 11:37		H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	ND	mg/L	0.10	0.10	1		07/25/17 19:00	18496-25-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: EB 1 **Lab ID: 92348734003** Collected: 07/21/17 10:17 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2140**	mg/L	44.0	22.0	44		07/26/17 19:46	14808-79-8	
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	**0.032J**	mg/L	0.050	0.025	1		07/26/17 12:53	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**5.3**	mg/L	1.0	0.50	1		07/29/17 20:44	16887-00-6	
Fluoride	**0.11**	mg/L	0.10	0.050	1		07/29/17 20:44	16984-48-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: FB 1 **Lab ID: 92348734004** Collected: 07/21/17 10:33 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	**49500**	ug/L	100	67.0	10	07/26/17 04:45	07/28/17 16:25	7429-90-5	D3
Antimony	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:25	7440-36-0	D3
Arsenic	**1.8**	ug/L	1.0	0.50	10	07/26/17 04:45	07/28/17 16:25	7440-38-2	D3
Barium	**22.1**	ug/L	3.0	1.1	10	07/26/17 04:45	07/28/17 16:25	7440-39-3	D3
Beryllium	**4.0**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:25	7440-41-7	D3
Cadmium	**2.0**	ug/L	0.80	0.60	10	07/26/17 04:45	07/28/17 16:25	7440-43-9	D3
Calcium	**540000**	ug/L	20000	10300	100	07/26/17 04:45	07/31/17 13:05	7440-70-2	D3
Chromium	**92.6**	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:25	7440-47-3	D3
Cobalt	**84.0**	ug/L	1.0	0.10	10	07/26/17 04:45	07/28/17 16:25	7440-48-4	D3
Copper	**123**	ug/L	5.0	1.2	10	07/26/17 04:45	07/28/17 16:25	7440-50-8	D3
Iron	**593000**	ug/L	5000	1180	100	07/26/17 04:45	07/31/17 13:05	7439-89-6	D3
Lead	**10**	ug/L	1.0	0.80	10	07/26/17 04:45	07/28/17 16:25	7439-92-1	D3
Lithium	**61.2**	ug/L	25.0	0.70	10	07/26/17 04:45	07/28/17 16:25	7439-93-2	D3
Magnesium	**29300**	ug/L	100	17.0	10	07/26/17 04:45	07/28/17 16:25	7439-95-4	D3
Manganese	**31700**	ug/L	50.0	19.0	100	07/26/17 04:45	07/31/17 13:05	7439-96-5	D3
Molybdenum	**14.0**	ug/L	5.0	1.1	10	07/26/17 04:45	07/28/17 16:25	7439-98-7	D3
Nickel	**95.7**	ug/L	5.0	4.5	10	07/26/17 04:45	07/28/17 16:25	7440-02-0	D3
Potassium	**17400**	ug/L	500	258	10	07/26/17 04:45	07/28/17 16:25	7440-09-7	D3
Selenium	**12.8**	ug/L	5.0	3.2	10	07/26/17 04:45	07/28/17 16:25	7782-49-2	D3
Silver	ND	ug/L	5.0	0.80	10	07/26/17 04:45	07/28/17 16:25	7440-22-4	D3
Sodium	**837000**	ug/L	25000	1290	100	07/26/17 04:45	07/31/17 13:05	7440-23-5	D3
Thallium	**0.27J**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:25	7440-28-0	D3
Vanadium	**17.9**	ug/L	5.0	0.70	10	07/26/17 04:45	07/28/17 16:25	7440-62-2	D3
Zinc	**2180**	ug/L	50.0	24.0	10	07/26/17 04:45	07/28/17 16:25	7440-66-6	D3
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	**403000**	ug/L	500	118	10	07/27/17 03:10	07/28/17 18:24	7439-89-6	
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**6750**	mg/L	12.5	12.5	1		07/26/17 00:15		
Total Volatile Solids	**1410**	mg/L	12.5	12.5	1		07/26/17 00:15		
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/27/17 23:40		
Alkalinity, Carbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/27/17 23:40		
Alkalinity, Total as CaCO3	ND	mg/L	5.0	1.0	1		07/27/17 23:40		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**4540**	mg/L	125	125	1		07/27/17 10:57		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**6.0**	Std. Units	1.0	0.10	1		07/28/17 11:37		H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	**15.7**	mg/L	2.5	2.5	25		07/25/17 19:00	18496-25-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: FB 1 **Lab ID: 92348734004** Collected: 07/21/17 10:33 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2270**	mg/L	46.0	23.0	46		07/26/17 20:03	14808-79-8	
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	**0.065**	mg/L	0.050	0.025	1		07/26/17 12:54	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**755**	mg/L	30.0	15.0	30		07/30/17 10:12	16887-00-6	
Fluoride	ND	mg/L	0.10	0.050	1		07/29/17 21:00	16984-48-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: NAOH 1 **Lab ID: 92348734005** Collected: 07/21/17 10:42 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	**526**	ug/L	100	67.0	10	07/26/17 04:45	07/28/17 16:27	7429-90-5	D3
Antimony	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:27	7440-36-0	D3
Arsenic	ND	ug/L	1.0	0.50	10	07/26/17 04:45	07/28/17 16:27	7440-38-2	D3
Barium	**12.2**	ug/L	3.0	1.1	10	07/26/17 04:45	07/28/17 16:27	7440-39-3	D3
Beryllium	ND	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:27	7440-41-7	D3
Cadmium	ND	ug/L	0.80	0.60	10	07/26/17 04:45	07/28/17 16:27	7440-43-9	D3
Calcium	**464000**	ug/L	2000	1030	10	07/26/17 04:45	07/28/17 16:27	7440-70-2	D3
Chromium	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:27	7440-47-3	D3
Cobalt	**3.5**	ug/L	1.0	0.10	10	07/26/17 04:45	07/28/17 16:27	7440-48-4	D3
Copper	**2.8J**	ug/L	5.0	1.2	10	07/26/17 04:45	07/28/17 16:27	7440-50-8	D3
Iron	**3060**	ug/L	500	118	10	07/26/17 04:45	07/28/17 16:27	7439-89-6	D3
Lead	ND	ug/L	1.0	0.80	10	07/26/17 04:45	07/28/17 16:27	7439-92-1	D3
Lithium	**109**	ug/L	25.0	0.70	10	07/26/17 04:45	07/28/17 16:27	7439-93-2	D3
Magnesium	**18700**	ug/L	100	17.0	10	07/26/17 04:45	07/28/17 16:27	7439-95-4	D3
Manganese	**4220**	ug/L	5.0	1.9	10	07/26/17 04:45	07/28/17 16:27	7439-96-5	D3
Molybdenum	ND	ug/L	5.0	1.1	10	07/26/17 04:45	07/28/17 16:27	7439-98-7	D3
Nickel	**4.9J**	ug/L	5.0	4.5	10	07/26/17 04:45	07/28/17 16:27	7440-02-0	D3
Potassium	**15000**	ug/L	500	258	10	07/26/17 04:45	07/28/17 16:27	7440-09-7	D3
Selenium	ND	ug/L	5.0	3.2	10	07/26/17 04:45	07/28/17 16:27	7782-49-2	D3
Silver	ND	ug/L	5.0	0.80	10	07/26/17 04:45	07/28/17 16:27	7440-22-4	D3
Sodium	**558000**	ug/L	12500	645	50	07/26/17 04:45	07/31/17 13:07	7440-23-5	D3
Thallium	**0.74J**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:27	7440-28-0	D3
Vanadium	ND	ug/L	5.0	0.70	10	07/26/17 04:45	07/28/17 16:27	7440-62-2	D3
Zinc	ND	ug/L	50.0	24.0	10	07/26/17 04:45	07/28/17 16:27	7440-66-6	D3
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	**17100**	ug/L	500	118	10	07/27/17 03:10	07/28/17 18:26	7439-89-6	
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**5620**	mg/L	12.5	12.5	1		07/26/17 00:15		
Total Volatile Solids	**615**	mg/L	12.5	12.5	1		07/26/17 00:15		
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	**454**	mg/L	5.0	1.0	1		07/28/17 11:01		
Alkalinity, Carbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/28/17 11:01		
Alkalinity, Total as CaCO3	**454**	mg/L	5.0	1.0	1		07/28/17 11:01		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**3530**	mg/L	50.0	50.0	1		07/28/17 13:48		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**7.5**	Std. Units	1.0	0.10	1		07/28/17 11:37		H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	ND	mg/L	0.10	0.10	1		07/25/17 19:00	18496-25-8	

REPORT OF LABORATORY ANALYSIS

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: NAOH 1 **Lab ID: 92348734005** Collected: 07/21/17 10:42 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2170**	mg/L	45.0	22.5	45		07/26/17 20:20	14808-79-8	
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	**0.029J**	mg/L	0.050	0.025	1		07/26/17 12:54	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**3.1**	mg/L	1.0	0.50	1		07/29/17 21:17	16887-00-6	
Fluoride	**0.29**	mg/L	0.10	0.050	1		07/29/17 21:17	16984-48-8	

ANALYTICAL RESULTS

Project:	COAL ASH
Pace Project No.:	92348734

Sample: ZVI 1 **Lab ID: 92348734006** Collected: 07/21/17 10:39 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	**5870**	ug/L	100	67.0	10	07/26/17 04:45	07/28/17 16:29	7429-90-5	D3
Antimony	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:29	7440-36-0	D3
Arsenic	**1.3**	ug/L	1.0	0.50	10	07/26/17 04:45	07/28/17 16:29	7440-38-2	D3
Barium	**17.2**	ug/L	3.0	1.1	10	07/26/17 04:45	07/28/17 16:29	7440-39-3	D3
Beryllium	**3.0**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:29	7440-41-7	D3
Cadmium	**2.8**	ug/L	0.80	0.60	10	07/26/17 04:45	07/28/17 16:29	7440-43-9	D3
Calcium	**480000**	ug/L	2000	1030	10	07/26/17 04:45	07/28/17 16:29	7440-70-2	D3
Chromium	**6.5**	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:29	7440-47-3	D3
Cobalt	**239**	ug/L	1.0	0.10	10	07/26/17 04:45	07/28/17 16:29	7440-48-4	D3
Copper	**9.7**	ug/L	5.0	1.2	10	07/26/17 04:45	07/28/17 16:29	7440-50-8	D3
Iron	**669000**	ug/L	5000	1180	100	07/26/17 04:45	07/31/17 13:09	7439-89-6	D3
Lead	**0.98J**	ug/L	1.0	0.80	10	07/26/17 04:45	07/28/17 16:29	7439-92-1	D3
Lithium	**108**	ug/L	25.0	0.70	10	07/26/17 04:45	07/28/17 16:29	7439-93-2	D3
Magnesium	**27000**	ug/L	100	17.0	10	07/26/17 04:45	07/28/17 16:29	7439-95-4	D3
Manganese	**28300**	ug/L	50.0	19.0	100	07/26/17 04:45	07/31/17 13:09	7439-96-5	D3
Molybdenum	ND	ug/L	5.0	1.1	10	07/26/17 04:45	07/28/17 16:29	7439-98-7	D3
Nickel	**116**	ug/L	5.0	4.5	10	07/26/17 04:45	07/28/17 16:29	7440-02-0	D3
Potassium	**14600**	ug/L	500	258	10	07/26/17 04:45	07/28/17 16:29	7440-09-7	D3
Selenium	**13.8**	ug/L	5.0	3.2	10	07/26/17 04:45	07/28/17 16:29	7782-49-2	D3
Silver	ND	ug/L	5.0	0.80	10	07/26/17 04:45	07/28/17 16:29	7440-22-4	D3
Sodium	**10700**	ug/L	2500	129	10	07/26/17 04:45	07/28/17 16:29	7440-23-5	D3
Thallium	ND	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:29	7440-28-0	D3
Vanadium	**8.9**	ug/L	5.0	0.70	10	07/26/17 04:45	07/28/17 16:29	7440-62-2	D3
Zinc	**885**	ug/L	50.0	24.0	10	07/26/17 04:45	07/28/17 16:29	7440-66-6	D3
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	**613000**	ug/L	1000	236	20	07/27/17 03:10	07/31/17 13:16	7439-89-6	
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**3980**	mg/L	12.5	12.5	1		07/26/17 00:15		
Total Volatile Solids	**795**	mg/L	12.5	12.5	1		07/26/17 00:15		
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/28/17 11:32		
Alkalinity, Carbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/28/17 11:32		
Alkalinity, Total as CaCO3	ND	mg/L	5.0	1.0	1		07/28/17 11:32		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**3680**	mg/L	50.0	50.0	1		07/27/17 10:58		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**5.5**	Std. Units	1.0	0.10	1		07/28/17 11:37		H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	**0.21**	mg/L	0.10	0.10	1		07/25/17 19:00	18496-25-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: ZVI 1 **Lab ID: 92348734006** Collected: 07/21/17 10:39 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2140**	mg/L	45.0	22.5	45		07/26/17 20:37	14808-79-8	
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	**0.055**	mg/L	0.050	0.025	1		07/26/17 12:55	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**2.9**	mg/L	1.0	0.50	1		07/29/17 21:33	16887-00-6	
Fluoride	**0.18**	mg/L	0.10	0.050	1		07/29/17 21:33	16984-48-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: CONT F2 **Lab ID: 92348734007** Collected: 07/21/17 11:55 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	**59900**	ug/L	100	67.0	10	07/26/17 04:45	07/28/17 16:53	7429-90-5	D3
Antimony	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:53	7440-36-0	D3
Arsenic	**2.1**	ug/L	1.0	0.50	10	07/26/17 04:45	07/28/17 16:53	7440-38-2	D3
Barium	**18.9**	ug/L	3.0	1.1	10	07/26/17 04:45	07/28/17 16:53	7440-39-3	D3
Beryllium	**11.5**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:53	7440-41-7	D3
Cadmium	**6.4**	ug/L	0.80	0.60	10	07/26/17 04:45	07/28/17 16:53	7440-43-9	D3
Calcium	**491000**	ug/L	2000	1030	10	07/26/17 04:45	07/28/17 16:53	7440-70-2	D3
Chromium	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:53	7440-47-3	D3
Cobalt	**312**	ug/L	1.0	0.10	10	07/26/17 04:45	07/28/17 16:53	7440-48-4	D3
Copper	**66.6**	ug/L	5.0	1.2	10	07/26/17 04:45	07/28/17 16:53	7440-50-8	D3
Iron	**343000**	ug/L	500	118	10	07/26/17 04:45	07/28/17 16:53	7439-89-6	D3
Lead	**28.0**	ug/L	1.0	0.80	10	07/26/17 04:45	07/28/17 16:53	7439-92-1	D3
Lithium	**113**	ug/L	25.0	0.70	10	07/26/17 04:45	07/28/17 16:53	7439-93-2	D3
Magnesium	**27900**	ug/L	100	17.0	10	07/26/17 04:45	07/28/17 16:53	7439-95-4	D3
Manganese	**27600**	ug/L	50.0	19.0	100	07/26/17 04:45	07/31/17 13:10	7439-96-5	D3
Molybdenum	ND	ug/L	5.0	1.1	10	07/26/17 04:45	07/28/17 16:53	7439-98-7	D3
Nickel	**171**	ug/L	5.0	4.5	10	07/26/17 04:45	07/28/17 16:53	7440-02-0	D3
Potassium	**15100**	ug/L	500	258	10	07/26/17 04:45	07/28/17 16:53	7440-09-7	D3
Selenium	**25.9**	ug/L	5.0	3.2	10	07/26/17 04:45	07/28/17 16:53	7782-49-2	D3
Silver	ND	ug/L	5.0	0.80	10	07/26/17 04:45	07/28/17 16:53	7440-22-4	D3
Sodium	**10400**	ug/L	2500	129	10	07/26/17 04:45	07/28/17 16:53	7440-23-5	D3
Thallium	**0.96J**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:53	7440-28-0	D3
Vanadium	ND	ug/L	5.0	0.70	10	07/26/17 04:45	07/28/17 16:53	7440-62-2	D3
Zinc	**1130**	ug/L	50.0	24.0	10	07/26/17 04:45	07/28/17 16:53	7440-66-6	D3
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	**347000**	ug/L	500	118	10	07/27/17 03:10	07/28/17 18:36	7439-89-6	
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**3920**	mg/L	12.5	12.5	1		07/27/17 21:21		
Total Volatile Solids	**630**	mg/L	12.5	12.5	1		07/27/17 21:21		D6
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/28/17 11:39		
Alkalinity, Carbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/28/17 11:39		
Alkalinity, Total as CaCO3	ND	mg/L	5.0	1.0	1		07/28/17 11:39		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**3200**	mg/L	125	125	1		07/27/17 10:58		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**3.0**	Std. Units	1.0	0.10	1		07/28/17 11:37		E,H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	ND	mg/L	0.10	0.10	1		07/25/17 19:00	18496-25-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: CONT F2 **Lab ID: 92348734007** Collected: 07/21/17 11:55 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2400**	mg/L	46.0	23.0	46		07/26/17 20:53	14808-79-8	
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	**0.031J**	mg/L	0.050	0.025	1		07/26/17 12:56	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**2.9**	mg/L	1.0	0.50	1		07/29/17 22:39	16887-00-6	
Fluoride	**0.37**	mg/L	0.10	0.050	1		07/29/17 22:39	16984-48-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: AMF 2 **Lab ID: 92348734008** Collected: 07/21/17 13:13 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	**34800**	ug/L	100	67.0	10	07/26/17 04:45	07/28/17 16:55	7429-90-5	D3
Antimony	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:55	7440-36-0	D3
Arsenic	**3.0**	ug/L	1.0	0.50	10	07/26/17 04:45	07/28/17 16:55	7440-38-2	D3
Barium	**4.2**	ug/L	3.0	1.1	10	07/26/17 04:45	07/28/17 16:55	7440-39-3	D3
Beryllium	**9.1**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:55	7440-41-7	D3
Cadmium	**5.9**	ug/L	0.80	0.60	10	07/26/17 04:45	07/28/17 16:55	7440-43-9	D3
Calcium	**448000**	ug/L	2000	1030	10	07/26/17 04:45	07/28/17 16:55	7440-70-2	D3
Chromium	**2.2J**	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:55	7440-47-3	D3
Cobalt	**295**	ug/L	1.0	0.10	10	07/26/17 04:45	07/28/17 16:55	7440-48-4	D3
Copper	**58.1**	ug/L	5.0	1.2	10	07/26/17 04:45	07/28/17 16:55	7440-50-8	D3
Iron	**311000**	ug/L	500	118	10	07/26/17 04:45	07/28/17 16:55	7439-89-6	D3
Lead	**3.5**	ug/L	1.0	0.80	10	07/26/17 04:45	07/28/17 16:55	7439-92-1	D3
Lithium	**113**	ug/L	25.0	0.70	10	07/26/17 04:45	07/28/17 16:55	7439-93-2	D3
Magnesium	**26300**	ug/L	100	17.0	10	07/26/17 04:45	07/28/17 16:55	7439-95-4	D3
Manganese	**22700**	ug/L	50.0	19.0	100	07/26/17 04:45	07/31/17 13:12	7439-96-5	D3
Molybdenum	**10.7**	ug/L	5.0	1.1	10	07/26/17 04:45	07/28/17 16:55	7439-98-7	D3
Nickel	**164**	ug/L	5.0	4.5	10	07/26/17 04:45	07/28/17 16:55	7440-02-0	D3
Potassium	**14200**	ug/L	500	258	10	07/26/17 04:45	07/28/17 16:55	7440-09-7	D3
Selenium	**19.0**	ug/L	5.0	3.2	10	07/26/17 04:45	07/28/17 16:55	7782-49-2	D3
Silver	ND	ug/L	5.0	0.80	10	07/26/17 04:45	07/28/17 16:55	7440-22-4	D3
Sodium	**953000**	ug/L	25000	1290	100	07/26/17 04:45	07/31/17 13:12	7440-23-5	D3
Thallium	**0.45J**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:55	7440-28-0	D3
Vanadium	**9.6**	ug/L	5.0	0.70	10	07/26/17 04:45	07/28/17 16:55	7440-62-2	D3
Zinc	**1160**	ug/L	50.0	24.0	10	07/26/17 04:45	07/28/17 16:55	7440-66-6	D3
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	**231000**	ug/L	500	118	10	07/27/17 03:10	07/28/17 18:38	7439-89-6	
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**7190**	mg/L	25.0	25.0	1		07/27/17 21:21		
Total Volatile Solids	**950**	mg/L	25.0	25.0	1		07/27/17 21:21		
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/28/17 11:45		
Alkalinity, Carbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/28/17 11:45		
Alkalinity, Total as CaCO3	ND	mg/L	5.0	1.0	1		07/28/17 11:45		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**5730**	mg/L	250	250	1		07/27/17 10:58		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**3.2**	Std. Units	1.0	0.10	1		07/28/17 11:37		E,H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	ND	mg/L	0.10	0.10	1		07/25/17 19:00	18496-25-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: AMF 2 **Lab ID: 92348734008** Collected: 07/21/17 13:13 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2070**	mg/L	100	50.0	100		07/26/17 21:10	14808-79-8	
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	**827**	mg/L	25.0	12.5	500		07/26/17 13:28	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**4.7**	mg/L	1.0	0.50	1		07/29/17 22:56	16887-00-6	
Fluoride	**0.22**	mg/L	0.10	0.050	1		07/29/17 22:56	16984-48-8	

ANALYTICAL RESULTS

Project:	COAL ASH
Pace Project No.:	92348734

Sample: EBF 2 **Lab ID: 92348734009** Collected: 07/21/17 14:39 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	ND	ug/L	100	67.0	10	07/26/17 04:45	07/28/17 16:57	7429-90-5	D3
Antimony	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:57	7440-36-0	D3
Arsenic	ND	ug/L	1.0	0.50	10	07/26/17 04:45	07/28/17 16:57	7440-38-2	D3
Barium	**20.8**	ug/L	3.0	1.1	10	07/26/17 04:45	07/28/17 16:57	7440-39-3	D3
Beryllium	ND	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:57	7440-41-7	D3
Cadmium	ND	ug/L	0.80	0.60	10	07/26/17 04:45	07/28/17 16:57	7440-43-9	D3
Calcium	**475000**	ug/L	2000	1030	10	07/26/17 04:45	07/28/17 16:57	7440-70-2	D3
Chromium	**1.2J**	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 16:57	7440-47-3	D3
Cobalt	**4.4**	ug/L	1.0	0.10	10	07/26/17 04:45	07/28/17 16:57	7440-48-4	D3
Copper	ND	ug/L	5.0	1.2	10	07/26/17 04:45	07/28/17 16:57	7440-50-8	D3
Iron	**138J**	ug/L	500	118	10	07/26/17 04:45	07/28/17 16:57	7439-89-6	D3
Lead	ND	ug/L	1.0	0.80	10	07/26/17 04:45	07/28/17 16:57	7439-92-1	D3
Lithium	**117**	ug/L	25.0	0.70	10	07/26/17 04:45	07/28/17 16:57	7439-93-2	D3
Magnesium	**272000**	ug/L	100	17.0	10	07/26/17 04:45	07/28/17 16:57	7439-95-4	D3
Manganese	**8560**	ug/L	25.0	9.5	50	07/26/17 04:45	07/31/17 13:14	7439-96-5	D3
Molybdenum	ND	ug/L	5.0	1.1	10	07/26/17 04:45	07/28/17 16:57	7439-98-7	D3
Nickel	ND	ug/L	5.0	4.5	10	07/26/17 04:45	07/28/17 16:57	7440-02-0	D3
Potassium	**14900**	ug/L	500	258	10	07/26/17 04:45	07/28/17 16:57	7440-09-7	D3
Selenium	ND	ug/L	5.0	3.2	10	07/26/17 04:45	07/28/17 16:57	7782-49-2	D3
Silver	ND	ug/L	5.0	0.80	10	07/26/17 04:45	07/28/17 16:57	7440-22-4	D3
Sodium	**11300**	ug/L	2500	129	10	07/26/17 04:45	07/28/17 16:57	7440-23-5	D3
Thallium	**0.75J**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 16:57	7440-28-0	D3
Vanadium	ND	ug/L	5.0	0.70	10	07/26/17 04:45	07/28/17 16:57	7440-62-2	D3
Zinc	ND	ug/L	50.0	24.0	10	07/26/17 04:45	07/28/17 16:57	7440-66-6	D3
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	**1400**	ug/L	500	118	10	07/27/17 03:10	07/28/17 18:40	7439-89-6	
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**3660**	mg/L	12.5	12.5	1		07/27/17 21:21		
Total Volatile Solids	**620**	mg/L	12.5	12.5	1		07/27/17 21:21		
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	**17.5**	mg/L	5.0	1.0	1		07/28/17 11:52		
Alkalinity, Carbonate (CaCO3)	ND	mg/L	5.0	1.0	1		07/28/17 11:52		
Alkalinity, Total as CaCO3	**17.5**	mg/L	5.0	1.0	1		07/28/17 11:52		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**2960**	mg/L	125	125	1		07/27/17 10:59		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**7.6**	Std. Units	1.0	0.10	1		07/28/17 11:37		H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	ND	mg/L	0.10	0.10	1		07/25/17 19:00	18496-25-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348734

Sample: EBF 2 **Lab ID: 92348734009** Collected: 07/21/17 14:39 Received: 07/24/17 12:11 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2090**	mg/L	44.0	22.0	44		07/26/17 21:27	14808-79-8	
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	**0.16**	mg/L	0.050	0.025	1		07/26/17 13:00	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**5.8**	mg/L	1.0	0.50	1		07/29/17 23:12	16887-00-6	
Fluoride	**0.099J**	mg/L	0.10	0.050	1		07/29/17 23:12	16984-48-8	

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch: 370524 Analysis Method: EPA 6020B
QC Batch Method: EPA 3010A Analysis Description: 6020 MET
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

METHOD BLANK: 2053188 Matrix: Water
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Aluminum	ug/L	ND	10.0	6.7	07/27/17 17:08	
Antimony	ug/L	ND	0.50	0.10	07/27/17 17:08	
Arsenic	ug/L	ND	0.10	0.050	07/27/17 17:08	
Barium	ug/L	ND	0.30	0.11	07/27/17 17:08	
Beryllium	ug/L	ND	0.10	0.020	07/27/17 17:08	
Cadmium	ug/L	ND	0.080	0.060	07/27/17 17:08	
Calcium	ug/L	ND	200	103	07/27/17 17:08	
Chromium	ug/L	ND	0.50	0.10	07/27/17 17:08	
Cobalt	ug/L	ND	0.10	0.010	07/27/17 17:08	
Copper	ug/L	ND	0.50	0.12	07/27/17 17:08	
Iron	ug/L	ND	50.0	11.8	07/27/17 17:08	
Lead	ug/L	ND	0.10	0.080	07/27/17 17:08	
Lithium	ug/L	ND	2.5	0.070	07/28/17 16:15	
Magnesium	ug/L	2.4J	10.0	1.7	07/27/17 17:08	
Manganese	ug/L	ND	0.50	0.19	07/27/17 17:08	
Molybdenum	ug/L	ND	0.50	0.11	07/27/17 17:08	
Nickel	ug/L	ND	0.50	0.45	07/27/17 17:08	
Potassium	ug/L	ND	50.0	25.8	07/27/17 17:08	
Selenium	ug/L	ND	0.50	0.32	07/27/17 17:08	
Silver	ug/L	ND	0.50	0.080	07/27/17 17:08	
Sodium	ug/L	19.9J	250	12.9	07/27/17 17:08	
Thallium	ug/L	ND	0.10	0.020	07/28/17 16:15	
Vanadium	ug/L	ND	0.50	0.070	07/27/17 17:08	
Zinc	ug/L	ND	5.0	2.4	07/27/17 17:08	

LABORATORY CONTROL SAMPLE: 2053189

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum	ug/L	100	101	101	80-120	
Antimony	ug/L	100	101	101	80-120	
Arsenic	ug/L	100	99.9	100	80-120	
Barium	ug/L	100	99.3	99	80-120	
Beryllium	ug/L	100	106	106	80-120	
Cadmium	ug/L	100	100	100	80-120	
Calcium	ug/L	1250	1150	92	80-120	
Chromium	ug/L	100	101	101	80-120	
Cobalt	ug/L	100	104	104	80-120	
Copper	ug/L	100	105	105	80-120	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

LABORATORY CONTROL SAMPLE: 2053189

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Iron	ug/L	1250	1270	101	80-120	
Lead	ug/L	100	95.2	95	80-120	
Lithium	ug/L	100	101	101	80-120	
Magnesium	ug/L	1250	1310	105	80-120	
Manganese	ug/L	100	101	101	80-120	
Molybdenum	ug/L	100	97.4	97	80-120	
Nickel	ug/L	100	105	105	80-120	
Potassium	ug/L	1250	1240	99	80-120	
Selenium	ug/L	100	96.1	96	80-120	
Silver	ug/L	100	100	100	80-120	
Sodium	ug/L	1250	1250	100	80-120	
Thallium	ug/L	100	100	100	80-120	
Vanadium	ug/L	100	99.3	99	80-120	
Zinc	ug/L	100	101	101	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053190 2053191

Parameter	Units	92348725007 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	ug/L	ND	100	100	98.6	102	98	101	75-125	4	20	
Antimony	ug/L	ND	100	100	103	102	103	102	75-125	1	20	
Arsenic	ug/L	ND	100	100	101	100	101	100	75-125	1	20	
Barium	ug/L	0.37	100	100	102	103	102	102	75-125	0	20	
Beryllium	ug/L	ND	100	100	103	102	103	102	75-125	1	20	
Cadmium	ug/L	ND	100	100	103	100	103	100	75-125	3	20	
Calcium	ug/L	ND	1250	1250	1240	1240	99	100	75-125	0	20	
Chromium	ug/L	0.61	100	100	105	104	104	104	75-125	0	20	
Cobalt	ug/L	0.021J	100	100	107	105	107	105	75-125	1	20	
Copper	ug/L	ND	100	100	107	106	107	106	75-125	1	20	
Iron	ug/L	ND	1250	1250	1310	1290	104	103	75-125	1	20	
Lead	ug/L	ND	100	100	95.7	97.0	96	97	75-125	1	20	
Lithium	ug/L	0.20J	100	100	107	106	106	106	75-125	0	20	
Magnesium	ug/L	2.4J	1250	1250	1340	1320	107	105	75-125	2	20	
Manganese	ug/L	0.46J	100	100	103	102	103	101	75-125	1	20	
Molybdenum	ug/L	ND	100	100	101	97.9	101	98	75-125	3	20	
Nickel	ug/L	0.90	100	100	108	106	107	105	75-125	2	20	
Potassium	ug/L	ND	1250	1250	1300	1260	104	101	75-125	3	20	
Selenium	ug/L	ND	100	100	98.5	96.9	99	97	75-125	2	20	
Silver	ug/L	ND	100	100	104	102	104	102	75-125	2	20	
Sodium	ug/L	19.0J	1250	1250	1280	1260	101	99	75-125	2	20	
Thallium	ug/L	ND	100	100	95.9	96.7	96	97	75-125	1	20	
Vanadium	ug/L	ND	100	100	103	100	103	100	75-125	3	20	
Zinc	ug/L	ND	100	100	106	102	106	102	75-125	3	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch: 370526 Analysis Method: EPA 6020B
QC Batch Method: EPA 3010A Analysis Description: 6020 MET Dissolved
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

METHOD BLANK: 2053196 Matrix: Water
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Iron, Dissolved	ug/L	ND	50.0	11.8	07/28/17 18:11	

LABORATORY CONTROL SAMPLE: 2053197

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Iron, Dissolved	ug/L	1250	1440	115	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053198 2053199

Parameter	Units	92348734001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Iron, Dissolved	ug/L	370000	1250	1250	335000	345000	-2810	-1970	75-125	3	20	M6

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch: 370700
Analysis Method: EPA 160.4
QC Batch Method: EPA 160.4
Analysis Description: 160.4 TVS and 2540B TS
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006

METHOD BLANK: 2054182
Matrix: Water
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Solids (SM 2540B)	mg/L	ND	2.5	2.5	07/26/17 00:15	
Total Volatile Solids	mg/L	ND	2.5	2.5	07/26/17 00:15	

LABORATORY CONTROL SAMPLE: 2054183

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Solids (SM 2540B)	mg/L	500	492	98	90-110	

SAMPLE DUPLICATE: 2054184

Parameter	Units	92348734001 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Solids (SM 2540B)	mg/L	3760	3690	2	10	
Total Volatile Solids	mg/L	700	580	19	10	D6

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch: 370701
Analysis Method: EPA 160.4
QC Batch Method: EPA 160.4
Analysis Description: 160.4 TVS and 2540B TS
Associated Lab Samples: 92348734007, 92348734008, 92348734009

METHOD BLANK: 2054185
Matrix: Water
Associated Lab Samples: 92348734007, 92348734008, 92348734009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Solids (SM 2540B)	mg/L	ND	2.5	2.5	07/27/17 21:21	
Total Volatile Solids	mg/L	ND	2.5	2.5	07/27/17 21:21	

LABORATORY CONTROL SAMPLE: 2054186

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Solids (SM 2540B)	mg/L	500	520	104	90-110	

SAMPLE DUPLICATE: 2054187

Parameter	Units	92348734007 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Solids (SM 2540B)	mg/L	3920	3920	0	10	
Total Volatile Solids	mg/L	630	540	15	10	D6

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch: 370555 Analysis Method: SM 2320B
QC Batch Method: SM 2320B Analysis Description: 2320B Alkalinity
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004

METHOD BLANK: 2053275 Matrix: Water
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Alkalinity, Carbonate (CaCO3)	mg/L	ND	5.0	1.0	07/27/17 18:29	
Alkalinity, Total as CaCO3	mg/L	ND	5.0	1.0	07/27/17 18:29	
Alkalinity,Bicarbonate (CaCO3)	mg/L	ND	5.0	1.0	07/27/17 18:29	

LABORATORY CONTROL SAMPLE: 2053276

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Alkalinity, Total as CaCO3	mg/L	50	47.3	95	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053277 2053278

Parameter	Units	92348725007 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Alkalinity, Total as CaCO3	mg/L	ND	50	50	48.7	48.9	97	98	80-120	1	25	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053279 2053280

Parameter	Units	92348728010 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Alkalinity, Total as CaCO3	mg/L	115	50	50	163	162	98	96	80-120	1	25	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch: 370727 | Analysis Method: SM 2320B
QC Batch Method: SM 2320B | Analysis Description: 2320B Alkalinity
Associated Lab Samples: 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

METHOD BLANK: 2054283 Matrix: Water
Associated Lab Samples: 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Alkalinity, Carbonate (CaCO3)	mg/L	ND	5.0	1.0	07/28/17 09:46	
Alkalinity, Total as CaCO3	mg/L	ND	5.0	1.0	07/28/17 09:46	
Alkalinity,Bicarbonate (CaCO3)	mg/L	ND	5.0	1.0	07/28/17 09:46	

LABORATORY CONTROL SAMPLE: 2054284

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Alkalinity, Total as CaCO3	mg/L	50	47.6	95	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2054285 2054286

Parameter	Units	92348772001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Alkalinity, Total as CaCO3	mg/L	83.8	50	50	130	125	92	83	80-120	3	25	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2054287 2054288

Parameter	Units	92348902001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Alkalinity, Total as CaCO3	mg/L	150	50	50	200	202	101	104	80-120	1	25	

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QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch:	370731	Analysis Method:	SM 2540C
QC Batch Method:	SM 2540C	Analysis Description:	2540C Total Dissolved Solids

Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734006, 92348734007, 92348734008, 92348734009

METHOD BLANK: 2054298 Matrix: Water

Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734006, 92348734007, 92348734008, 92348734009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Dissolved Solids	mg/L	ND	25.0	25.0	07/27/17 10:55	

LABORATORY CONTROL SAMPLE: 2054299

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Dissolved Solids	mg/L	250	236	94	90-110	

SAMPLE DUPLICATE: 2054300

Parameter	Units	92347933009 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Dissolved Solids	mg/L	674	670	1	5	H1

SAMPLE DUPLICATE: 2054301

Parameter	Units	92348800001 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Dissolved Solids	mg/L	1460	1450	0	5	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch: 370998
QC Batch Method: SM 2540C
Analysis Method: SM 2540C
Analysis Description: 2540C Total Dissolved Solids
Associated Lab Samples: 92348734005

METHOD BLANK: 2055648
Matrix: Water
Associated Lab Samples: 92348734005

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Dissolved Solids	mg/L	ND	25.0	25.0	07/28/17 13:36	

LABORATORY CONTROL SAMPLE: 2055649

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Dissolved Solids	mg/L	250	236	94	90-110	

SAMPLE DUPLICATE: 2055650

Parameter	Units	92348842001 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Dissolved Solids	mg/L	464	472	2	5	

SAMPLE DUPLICATE: 2055651

Parameter	Units	92348842011 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Dissolved Solids	mg/L	609	604	1	5	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch: 370932
Analysis Method: SM 4500-H+B
QC Batch Method: SM 4500-H+B
Analysis Description: 4500H+B pH
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

SAMPLE DUPLICATE: 2055410

Parameter	Units	92348734001 Result	Dup Result	RPD	Max RPD	Qualifiers
pH at 25 Degrees C	Std. Units	3.0	3.0	0	10	E,H6

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch:	370499	Analysis Method:	SM 4500-S2D
QC Batch Method:	SM 4500-S2D	Analysis Description:	4500S2D Sulfide Water

Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

METHOD BLANK: 2053011 Matrix: Water

Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Sulfide	mg/L	ND	0.10	0.10	07/25/17 19:00	

LABORATORY CONTROL SAMPLE: 2053012

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Sulfide	mg/L	.5	0.50	100	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053013 2053014

Parameter	Units	92348728015 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Sulfide	mg/L	ND	.5	.5	0.59	0.58	118	115	80-120	2	10	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053015 2053016

Parameter	Units	92348734001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Sulfide	mg/L	ND	.5	.5	0.51	0.51	99	100	80-120	1	10	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch: 370425 Analysis Method: EPA 300.0
QC Batch Method: EPA 300.0 Analysis Description: 300.0 IC Anions
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

METHOD BLANK: 2052465 Matrix: Water
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Sulfate	mg/L	ND	1.0	0.50	07/26/17 02:47	

LABORATORY CONTROL SAMPLE: 2052466

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Sulfate	mg/L	50	52.8	106	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2052467 2052468

Parameter	Units	92348734001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Sulfate	mg/L	2230	50	50	2480	2490	512	522	90-110	0	10	M6

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2052469 2052470

Parameter	Units	92348525003 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Sulfate	mg/L	163	50	50	214	207	100	86	90-110	3	10	M6

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch: 370388
Analysis Method: EPA 365.1
QC Batch Method: EPA 365.1
Analysis Description: 365.1 Phosphorus, Total
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

METHOD BLANK: 2052278
Matrix: Water
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Phosphorus	mg/L	ND	0.050	0.025	07/26/17 12:32	

LABORATORY CONTROL SAMPLE: 2052279

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Phosphorus	mg/L	2.5	2.6	104	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2052280 2052281

Parameter	Units	92348246002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Phosphorus	mg/L	9.0	2.5	2.5	11.8	11.3	111	94	90-110	4	10	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2052282 2052283

Parameter	Units	92348734007 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Phosphorus	mg/L	0.031J	2.5	2.5	2.3	2.3	89	90	90-110	1	10	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348734

QC Batch: 370559 Analysis Method: EPA 9056A
QC Batch Method: EPA 9056A Analysis Description: 9056 IC anions 28 Days
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

METHOD BLANK: 2053291 Matrix: Water
Associated Lab Samples: 92348734001, 92348734002, 92348734003, 92348734004, 92348734005, 92348734006, 92348734007, 92348734008, 92348734009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Chloride	mg/L	ND	1.0	0.50	07/29/17 17:42	
Fluoride	mg/L	ND	0.10	0.050	07/29/17 17:42	

LABORATORY CONTROL SAMPLE: 2053292

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Chloride	mg/L	50	52.1	104	90-110	
Fluoride	mg/L	2.5	2.7	106	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053293 2053294

Parameter	Units	92348734001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Chloride	mg/L	2.9	50	50	55.8	55.8	106	106	90-110	0	10	
Fluoride	mg/L	0.40	2.5	2.5	2.8	2.8	96	96	90-110	1	10	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053295 2053296

Parameter	Units	92348882002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Chloride	mg/L	4.3	50	50	57.2	57.4	106	106	90-110	0	10	
Fluoride	mg/L	0.24	2.5	2.5	2.8	2.8	102	101	90-110	1	10	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALIFIERS

Project: COAL ASH
Pace Project No.: 92348734

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to dilution of the sample aliquot.

ND - Not Detected at or above adjusted reporting limit.

TNTC - Too Numerous To Count

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

PQL - Practical Quantitation Limit.

RL - Reporting Limit.

S - Surrogate

1,2-Diphenylhydrazine decomposes to and cannot be separated from Azobenzene using Method 8270. The result for each analyte is a combined concentration.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

Acid preservation may not be appropriate for 2 Chloroethylvinyl ether.

A separate vial preserved to a pH of 4-5 is recommended in SW846 Chapter 4 for the analysis of Acrolein and Acrylonitrile by EPA Method 8260.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

TNI - The NELAC Institute.

LABORATORIES

PASI-A	Pace Analytical Services - Asheville

ANALYTE QUALIFIERS

D3	Sample was diluted due to the presence of high levels of non-target analytes or other matrix interference.
D6	The precision between the sample and sample duplicate exceeded laboratory control limits.
E	Analyte concentration exceeded the calibration range. The reported result is estimated.
H1	Analysis conducted outside the EPA method holding time.
H6	Analysis initiated outside of the 15 minute EPA required holding time.
M6	Matrix spike and Matrix spike duplicate recovery not evaluated against control limits due to sample dilution.

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project:	COAL ASH
Pace Project No.:	92348734

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
92348734001	**CONT 1**	EPA 3010A	370524	EPA 6020B	370765
92348734002	**AM 1**	EPA 3010A	370524	EPA 6020B	370765
92348734003	**EB 1**	EPA 3010A	370524	EPA 6020B	370765
92348734004	**FB 1**	EPA 3010A	370524	EPA 6020B	370765
92348734005	**NAOH 1**	EPA 3010A	370524	EPA 6020B	370765
92348734006	**ZVI 1**	EPA 3010A	370524	EPA 6020B	370765
92348734007	**CONT F2**	EPA 3010A	370524	EPA 6020B	370765
92348734008	**AMF 2**	EPA 3010A	370524	EPA 6020B	370765
92348734009	**EBF 2**	EPA 3010A	370524	EPA 6020B	370765
92348734001	**CONT 1**	EPA 3010A	370526	EPA 6020B	370767
92348734002	**AM 1**	EPA 3010A	370526	EPA 6020B	370767
92348734003	**EB 1**	EPA 3010A	370526	EPA 6020B	370767
92348734004	**FB 1**	EPA 3010A	370526	EPA 6020B	370767
92348734005	**NAOH 1**	EPA 3010A	370526	EPA 6020B	370767
92348734006	**ZVI 1**	EPA 3010A	370526	EPA 6020B	370767
92348734007	**CONT F2**	EPA 3010A	370526	EPA 6020B	370767
92348734008	**AMF 2**	EPA 3010A	370526	EPA 6020B	370767
92348734009	**EBF 2**	EPA 3010A	370526	EPA 6020B	370767
92348734001	**CONT 1**	EPA 160.4	370700		
92348734002	**AM 1**	EPA 160.4	370700		
92348734003	**EB 1**	EPA 160.4	370700		
92348734004	**FB 1**	EPA 160.4	370700		
92348734005	**NAOH 1**	EPA 160.4	370700		
92348734006	**ZVI 1**	EPA 160.4	370700		
92348734007	**CONT F2**	EPA 160.4	370701		
92348734008	**AMF 2**	EPA 160.4	370701		
92348734009	**EBF 2**	EPA 160.4	370701		
92348734001	**CONT 1**	SM 2320B	370555		
92348734002	**AM 1**	SM 2320B	370555		
92348734003	**EB 1**	SM 2320B	370555		
92348734004	**FB 1**	SM 2320B	370555		
92348734005	**NAOH 1**	SM 2320B	370727		
92348734006	**ZVI 1**	SM 2320B	370727		
92348734007	**CONT F2**	SM 2320B	370727		
92348734008	**AMF 2**	SM 2320B	370727		
92348734009	**EBF 2**	SM 2320B	370727		
92348734001	**CONT 1**	SM 2540C	370731		
92348734002	**AM 1**	SM 2540C	370731		
92348734003	**EB 1**	SM 2540C	370731		
92348734004	**FB 1**	SM 2540C	370731		
92348734005	**NAOH 1**	SM 2540C	370998		
92348734006	**ZVI 1**	SM 2540C	370731		
92348734007	**CONT F2**	SM 2540C	370731		
92348734008	**AMF 2**	SM 2540C	370731		
92348734009	**EBF 2**	SM 2540C	370731		

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: COAL ASH
Pace Project No.: 92348734

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
92348734001	**CONT 1**	SM 4500-H+B	370932		
92348734002	**AM 1**	SM 4500-H+B	370932		
92348734003	**EB 1**	SM 4500-H+B	370932		
92348734004	**FB 1**	SM 4500-H+B	370932		
92348734005	**NAOH 1**	SM 4500-H+B	370932		
92348734006	**ZVI 1**	SM 4500-H+B	370932		
92348734007	**CONT F2**	SM 4500-H+B	370932		
92348734008	**AMF 2**	SM 4500-H+B	370932		
92348734009	**EBF 2**	SM 4500-H+B	370932		
92348734001	**CONT 1**	SM 4500-S2D	370499		
92348734002	**AM 1**	SM 4500-S2D	370499		
92348734003	**EB 1**	SM 4500-S2D	370499		
92348734004	**FB 1**	SM 4500-S2D	370499		
92348734005	**NAOH 1**	SM 4500-S2D	370499		
92348734006	**ZVI 1**	SM 4500-S2D	370499		
92348734007	**CONT F2**	SM 4500-S2D	370499		
92348734008	**AMF 2**	SM 4500-S2D	370499		
92348734009	**EBF 2**	SM 4500-S2D	370499		
92348734001	**CONT 1**	EPA 300.0	370425		
92348734002	**AM 1**	EPA 300.0	370425		
92348734003	**EB 1**	EPA 300.0	370425		
92348734004	**FB 1**	EPA 300.0	370425		
92348734005	**NAOH 1**	EPA 300.0	370425		
92348734006	**ZVI 1**	EPA 300.0	370425		
92348734007	**CONT F2**	EPA 300.0	370425		
92348734008	**AMF 2**	EPA 300.0	370425		
92348734009	**EBF 2**	EPA 300.0	370425		
92348734001	**CONT 1**	EPA 365.1	370388		
92348734002	**AM 1**	EPA 365.1	370388		
92348734003	**EB 1**	EPA 365.1	370388		
92348734004	**FB 1**	EPA 365.1	370388		
92348734005	**NAOH 1**	EPA 365.1	370388		
92348734006	**ZVI 1**	EPA 365.1	370388		
92348734007	**CONT F2**	EPA 365.1	370388		
92348734008	**AMF 2**	EPA 365.1	370388		
92348734009	**EBF 2**	EPA 365.1	370388		
92348734001	**CONT 1**	EPA 9056A	370559		
92348734002	**AM 1**	EPA 9056A	370559		
92348734003	**EB 1**	EPA 9056A	370559		
92348734004	**FB 1**	EPA 9056A	370559		
92348734005	**NAOH 1**	EPA 9056A	370559		
92348734006	**ZVI 1**	EPA 9056A	370559		
92348734007	**CONT F2**	EPA 9056A	370559		
92348734008	**AMF 2**	EPA 9056A	370559		
92348734009	**EBF 2**	EPA 9056A	370559		

Pace Analytical®	Document Name: **Sample Condition Upon Receipt(SCUR)**	Document Revised: Sept. 21, 2016 Page 1 of 2
	Document No.: **F-CAR-CS-033-Rev.01**	Issuing Authority: Pace Quality Office

Laboratory receiving samples:

Asheville ☐ **Eden** ☐ **Greenwood** ☐ **Huntersville** ☑ **Raleigh** ☐ **Mechanicsville** ☐

Sample Condition Upon Receipt **Client Name:** Redox Tech LLC **Project #:** WO# : 92348734

92348734

Courier: ☐ Commercial ☐ Fed Ex ☑ Pace ☐ UPS ☐ USPS ☐ Other:____ ☐ Client

Custody Seal Present? ☐ Yes ☑ No **Seals Intact?** ☐ Yes ☑ No

Date/Initials Person Examining Contents: 7-24-17 n

Packing Material: ☐ Bubble Wrap ☐ Bubble Bags ☑ None ☐ Other:____

Thermometer: ☐ IR Gun ID: T1603 **Type of Ice:** ☑ Wet ☐ Blue ☐ None ☑ Samples on ice, cooling process has begun

Correction Factor: **Cooler Temp Corrected (°C):** 3.9 **Biological Tissue Frozen?** ☐ Yes ☑ No ☐ N/A

Temp should be above freezing to 6°C

USDA Regulated Soil (☑ N/A, water sample)

Did samples originate in a quarantine zone within the United States: CA, NY, or SC (check maps)? ☐ Yes ☑ No

Did samples originate from a foreign source (internationally, including Hawaii and Puerto Rico)? ☐ Yes ☑ No

				Comments/Discrepancy:
Chain of Custody Present?	☑ Yes	☐ No	☐ N/A	1.
Samples Arrived within Hold Time?	☑ Yes	☐ No	☐ N/A	2.
Short Hold Time Analysis (<72 hr.)?	☐ Yes	☑ No	☐ N/A	3.
Rush Turn Around Time Requested?	☐ Yes	☑ No	☐ N/A	4.
Sufficient Volume?	☑ Yes	☐ No	☐ N/A	5.
Correct Containers Used?	☑ Yes	☐ No	☐ N/A	6.
-Pace Containers Used?	☑ Yes	☐ No	☐ N/A	
Containers Intact?	☑ Yes	☐ No	☐ N/A	7.
Samples Field Filtered?	☐ Yes	☑ No	☐ N/A	8. Note if sediment is visible in the dissolved container
Sample Labels Match COC?	☑ Yes	☐ No	☐ N/A	9.
-Includes Date/Time/ID/Analysis Matrix: WT				
Headspace in VOA Vials (>5-6mm)?	☐ Yes	☐ No	☑ N/A	10.
Trip Blank Present?	☐ Yes	☑ No	☐ N/A	11.
Trip Blank Custody Seals Present?	☐ Yes	☐ No	☑ N/A	

CLIENT NOTIFICATION/RESOLUTION

Field Data Required? ☐ Yes ☐ No

Person Contacted: Joe Rassabi Date/Time: 7/24/17 15:45

Comments/Sample Discrepancy: Client provided table of analyses for log-in. Samples were logged in for analyses based on table provided, not on COC. NMG 7/25/17

Project Manager SCURF Review: NMG **Date:** 7/24/17

Project Manager SRF Review: NMG **Date:** 7/25/17

Note: Whenever there is a discrepancy affecting North Carolina compliance samples, a copy of this form will be sent to the North Carolina DEHNR Certification Office (i.e. Out of hold, incorrect preservative, out of temp, incorrect containers)

Pace Analytical	Document Name: **Sample Condition Upon Receipt(SCUR)**	Document Revised: Sept. 21, 2016 Page 2 of 2
	Document No.: **F-CAR-CS-033-Rev.01**	Issuing Authority: Pace Quality Office

***Check mark top half of box if pH and/or dechlorination is verified and within the acceptance range for preservation samples.**

****Bottom half of box is to list number of bottles**

Project # **WO#: 92348734**

PM: PTE Due Date: 07/31/17

CLIENT: 92-RedoxTech

Item#	**BP4U**-125 mL Plastic Unpreserved (N/A) (Cl-)	**BP3U**-250 mL Plastic Unpreserved (N/A)	**BP2U**-500 mL Plastic Unpreserved (N/A)	**BP1U**-1 liter Plastic Unpreserved (N/A)	**BP3S**-250 mL Plastic H2SO4 (pH < 2) (Cl-)	**BP3N**-250 mL plastic HNO3 (pH < 2)	**BP3Z**-250 mL Plastic ZN Acetate & NaOH (>9)	**BP3C**-250 mL Plastic NaOH (pH > 12) (Cl-)	**WGFU**-Wide-mouthed Glass jar Unpreserved	**AG1U**-1 liter Amber Unpreserved (N/A) (Cl-)	**AG1H**-1 liter Amber HCl (pH < 2)	**AG3U**-250 mL Amber Unpreserved (N/A) (Cl-)	**AG1S**-1 liter Amber H2SO4 (pH < 2)	**AG3S**-250 mL Amber H2SO4 (pH < 2)	**AG3A(DG3A)**-250 mL Amber NH4Cl (N/A)(Cl-)	**DG9H**-40 mL VOA HCl (N/A)	**VG9T**-40 mL VOA Na2S2O3 (N/A)	**VG9U**-40 mL VOA Unp (N/A)	**DG9P**-40 mL VOA H3PO4 (N/A)	**VOAK (6 vials per kit)**-5035 kit (N/A)	**V/GK (3 vials per kit)**-VPH/Gas kit (N/A)	**SP5T**-125 mL Sterile Plastic (N/A – lab)	**SP2T**-250 mL Sterile Plastic (N/A – lab)		**BP3A**-250 mL Plastic (NH2)2SO4 (9.3-9.7)	**Cubitainer**	**VSGU**-20 mL Scintillation vials **(N/A)**	**GN**
1	2	1		2	✓ 1	✓ 1	✓ 1																					
2	1	1		2	✓ 1	✓ 1	✓ 1																					
3	1	1		2	✓ 1	✓ 1	✓ 1																					
4	1	1		2	✓ 1	✓ 1	✓ 1																					
5	1	1		2	✓ 1	✓ 1	✓ 1																					
6	1	1		2	✓ 1	✓ 1	✓ 1																					
7	1	1		2	✓ 1	✓ 1	✓ 1																					
8	1	1		2	✓ 1	✓ 1	✓ 1																					
9	1	1		2	✓ 1	✓ 1	✓ 1																					
10																												
11																												
12																												

pH Adjustment Log for Preserved Samples

Sample ID	Type of Preservative	pH upon receipt	Date preservation adjusted	Time preservation adjusted	Amount of Preservative added	Lot #

Pace Analytical

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page : 1 Of 1

Section A
Required Client Information:
Company: Redox Tech, LLC
Address: 200 Quade Dr
Cary, NC 27513
Email: rossabi@redox-tech.com
Phone: 919 678-0140 Fax 919 678-0150
Requested Due Date: 5 days

Section B
Required Project Information:
Report To: Joe Rossabi
Copy To:
Purchase Order #:
Project Name: Coal Ash
Project #:

Section C
Invoice Information:
Attention:
Company Name:
Address:
Pace Quote:
Pace Project Manager: taylor.ezell@pacelabs.com,
Pace Profile #: 8670-1

Regulatory Agency:
State / Location: NC

MATRIX / CODE
Drinking Water DW
Water WT
Waste Water WW
Product P
Soil/Solid SL
Oil OL
Wipe WP
Air AR
Other OT
Tissue TS

SAMPLE ID: One Character per box. (A-Z, 0-9 / , -) Sample Ids must be unique

Requested Analysis Filtered (Y/N)

92348734

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED START DATE	COLLECTED START TIME	COLLECTED END DATE	COLLECTED END TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Unpreserved	H2SO4	HNO3	HCl	NaOH	Na2S2O3	Methanol	Other	Analyses Test Y/N	Alkalinity, TDS, TS	Chloride, Fluoride	Ignitability	Total Phosphorus	Sulfide	Total Metals	Residual Chlorine (Y/N)	
1	CONT 1			7/21/17	9:39				7	4	4	1		1					✓	✓	✓	✓	✓	✓		001
2	AM 1			7/21/17	10:09				7	4	1	1		1					✓	✓	✓	✓	✓	✓		002
3	EB 1			7/21/17	10:17				7	4	1	1		1					✓	✓	✓	✓	✓	✓		003
4	FB 1			7/21/17	10:33				7	4	1	1		1					✓	✓	✓	✓	✓	✓		004
5	NaOH 1			7/21/17	10:42				7	4	1	1		1					✓	✓	✓	✓	✓	✓		005
6	ZVI 1			7/21/17	10:39				7	4	1	1		1					✓	✓	✓	✓	✓	✓		006
7	CONTF 2			7/21/17	11:55				7	4	1	1		1					✓	✓	✓	✓	✓	✓		007
8	AMF 2			7/21/17	13:13				7	4	1	1		1					✓	✓	✓	✓	✓	✓		008
9	EBF 2			7/21/17	14:39				7	4	1	1		1					✓	✓	✓	✓	✓	✓		009
10	~~FBF 2~~			~~7/21/17~~																						
11	~~NaOH F 2~~			~~7/21/17~~																						
12	~~ZVI F2~~			~~7/21/17~~					~~7~~	~~4~~	~~1~~	~~1~~		~~1~~					~~✓~~	~~✓~~	~~✓~~	~~✓~~	~~✓~~	~~✓~~		

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	TEMP in C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)
	Kyle Baseley (Redox)	7/21	16:29	Pace	7/21	16:29		Y	✓	Y
	Pace			J Johns Pace	7-24-17	1006				
	J Johns Pace	7-24-17	1211	Pace HH	7-24-17	1211	3.9	Y	N	Y

SAMPLER NAME AND SIGNATURE
PRINT Name of SAMPLER: ROSSABI
SIGNATURE of SAMPLER:
DATE Signed: 7/21/17

Pace Analytical Services, LLC
9800 Kincey Ave. Suite 100
Huntersville, NC 28078
(704)875-9092

August 02, 2017

Joe Rassabi

200 Quade Drive
Cary, NC 27513

RE: Project: COAL ASH
Pace Project No.: 92348882

Dear Joe Rassabi:

Enclosed are the analytical results for sample(s) received by the laboratory on July 25, 2017. The results relate only to the samples included in this report. Results reported herein conform to the most current, applicable TNI/NELAC standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Taylor Ezell
taylor.ezell@pacelabs.com
(704)875-9092
Project Manager

Enclosures

cc: John Haselow, Redox Tech, LLC

CERTIFICATIONS

Project:	COAL ASH
Pace Project No.:	92348882

Asheville Certification IDs

2225 Riverside Drive, Asheville, NC 28804
Florida/NELAP Certification #: E87648
Massachusetts Certification #: M-NC030
North Carolina Drinking Water Certification #: 37712
North Carolina Wastewater Certification #: 40
South Carolina Certification #: 99030001
Virginia/VELAP Certification #: 460222

SAMPLE SUMMARY

Project: COAL ASH
Pace Project No.: 92348882

Lab ID	Sample ID	Matrix	Date Collected	Date Received
92348882001	**FB F2**	Water	07/24/17 08:42	07/25/17 07:46
92348882002	**NAOH F2**	Water	07/24/17 10:50	07/25/17 07:46
92348882003	**ZVI F2**	Water	07/24/17 13:55	07/25/17 07:46

SAMPLE ANALYTE COUNT

Project: COAL ASH
Pace Project No.: 92348882

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
92348882001	**FB F2**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	1	PASI-A
		SM 2540C	SLB	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	NAL	1	PASI-A
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	CJH1	1	PASI-A
		EPA 9056A	CDC	2	PASI-A
92348882002	**NAOH F2**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	1	PASI-A
		SM 2540C	NAL	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	NAL	1	PASI-A
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	CJH1	1	PASI-A
		EPA 9056A	CDC	2	PASI-A
92348882003	**ZVI F2**	EPA 6020B	CDF	24	PASI-A
		EPA 6020B	CDF	1	PASI-A
		EPA 160.4	SLB	2	PASI-A
		SM 2320B	KDF1	1	PASI-A
		SM 2540C	NAL	1	PASI-A
		SM 4500-H+B	ECH	1	PASI-A
		SM 4500-S2D	NAL	1	PASI-A
		EPA 300.0	CDC	1	PASI-A
		EPA 365.1	CJH1	1	PASI-A
		EPA 9056A	CDC	2	PASI-A

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348882

Sample: FB F2 **Lab ID: 92348882001** Collected: 07/24/17 08:42 Received: 07/25/17 07:46 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	**69.6J**	ug/L	100	67.0	10	07/26/17 04:45	07/28/17 18:01	7429-90-5	
Antimony	ND	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 18:01	7440-36-0	
Arsenic	ND	ug/L	1.0	0.50	10	07/26/17 04:45	07/28/17 18:01	7440-38-2	
Barium	**57.2**	ug/L	3.0	1.1	10	07/26/17 04:45	07/28/17 18:01	7440-39-3	
Beryllium	**0.22J**	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 18:01	7440-41-7	
Cadmium	ND	ug/L	0.80	0.60	10	07/26/17 04:45	07/28/17 18:01	7440-43-9	
Calcium	**5610**	ug/L	2000	1030	10	07/26/17 04:45	07/28/17 18:01	7440-70-2	
Chromium	**1.3J**	ug/L	5.0	1.0	10	07/26/17 04:45	07/28/17 18:01	7440-47-3	B
Cobalt	**0.29J**	ug/L	1.0	0.10	10	07/26/17 04:45	07/28/17 18:01	7440-48-4	
Copper	ND	ug/L	5.0	1.2	10	07/26/17 04:45	07/28/17 18:01	7440-50-8	
Iron	ND	ug/L	500	118	10	07/26/17 04:45	07/28/17 18:01	7439-89-6	
Lead	ND	ug/L	1.0	0.80	10	07/26/17 04:45	07/28/17 18:01	7439-92-1	
Lithium	**13.5J**	ug/L	25.0	0.70	10	07/26/17 04:45	07/28/17 18:01	7439-93-2	
Magnesium	**3780**	ug/L	100	17.0	10	07/26/17 04:45	07/28/17 18:01	7439-95-4	
Manganese	**12.3**	ug/L	5.0	1.9	10	07/26/17 04:45	07/28/17 18:01	7439-96-5	
Molybdenum	ND	ug/L	5.0	1.1	10	07/26/17 04:45	07/28/17 18:01	7439-98-7	
Nickel	ND	ug/L	5.0	4.5	10	07/26/17 04:45	07/28/17 18:01	7440-02-0	
Potassium	**2640**	ug/L	500	258	10	07/26/17 04:45	07/28/17 18:01	7440-09-7	
Selenium	ND	ug/L	5.0	3.2	10	07/26/17 04:45	07/28/17 18:01	7782-49-2	
Silver	ND	ug/L	5.0	0.80	10	07/26/17 04:45	07/28/17 18:01	7440-22-4	
Sodium	**7540**	ug/L	2500	129	10	07/26/17 04:45	07/28/17 18:01	7440-23-5	
Thallium	ND	ug/L	1.0	0.20	10	07/26/17 04:45	07/28/17 18:01	7440-28-0	
Vanadium	**3.5J**	ug/L	5.0	0.70	10	07/26/17 04:45	07/28/17 18:01	7440-62-2	
Zinc	ND	ug/L	50.0	24.0	10	07/26/17 04:45	07/28/17 18:01	7440-66-6	
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	**387000**	ug/L	500	118	10	07/27/17 03:10	07/28/17 18:42	7439-89-6	
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**980**	mg/L	2.5	2.5	1		07/27/17 21:21		
Total Volatile Solids	**132**	mg/L	2.5	2.5	1		07/27/17 21:21		
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity, Total as CaCO3	ND	mg/L	5.0	1.0	1		07/28/17 12:32		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**4620**	mg/L	125	125	1		07/31/17 15:24		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**4.3**	Std. Units	1.0	0.10	1		07/31/17 13:37		H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	**0.88**	mg/L	0.50	0.50	5		07/31/17 17:42	18496-25-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348882

Sample: FB F2 **Lab ID: 92348882001** Collected: 07/24/17 08:42 Received: 07/25/17 07:46 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2740**	mg/L	47.0	23.5	47		07/30/17 10:45	14808-79-8	
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	**0.031J**	mg/L	0.050	0.025	1		08/01/17 06:17	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**804**	mg/L	47.0	23.5	47		07/30/17 10:45	16887-00-6	
Fluoride	ND	mg/L	0.10	0.050	1		07/29/17 23:28	16984-48-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348882

Sample: NAOH F2 **Lab ID: 92348882002** Collected: 07/24/17 10:50 Received: 07/25/17 07:46 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	**77.8J**	ug/L	100	67.0	10	07/27/17 02:25	07/28/17 19:00	7429-90-5	
Antimony	ND	ug/L	5.0	1.0	10	07/27/17 02:25	07/28/17 19:00	7440-36-0	
Arsenic	ND	ug/L	1.0	0.50	10	07/27/17 02:25	07/31/17 13:42	7440-38-2	
Barium	**9.9**	ug/L	3.0	1.1	10	07/27/17 02:25	07/28/17 19:00	7440-39-3	
Beryllium	ND	ug/L	1.0	0.20	10	07/27/17 02:25	07/28/17 19:00	7440-41-7	
Cadmium	ND	ug/L	0.80	0.60	10	07/27/17 02:25	07/28/17 19:00	7440-43-9	
Calcium	**486000**	ug/L	2000	1030	10	07/27/17 02:25	07/28/17 19:00	7440-70-2	M6
Chromium	**1.2J**	ug/L	5.0	1.0	10	07/27/17 02:25	07/31/17 13:42	7440-47-3	
Cobalt	**6.3**	ug/L	1.0	0.10	10	07/27/17 02:25	07/28/17 19:00	7440-48-4	
Copper	ND	ug/L	5.0	1.2	10	07/27/17 02:25	07/28/17 19:00	7440-50-8	
Iron	**762**	ug/L	500	118	10	07/27/17 02:25	07/28/17 19:00	7439-89-6	
Lead	ND	ug/L	1.0	0.80	10	07/27/17 02:25	07/28/17 19:00	7439-92-1	
Lithium	**99.0**	ug/L	25.0	0.70	10	07/27/17 02:25	07/28/17 19:00	7439-93-2	
Magnesium	**23200**	ug/L	100	17.0	10	07/27/17 02:25	07/28/17 19:00	7439-95-4	M6
Manganese	**8470**	ug/L	25.0	9.5	50	07/27/17 02:25	07/31/17 14:17	7439-96-5	M6
Molybdenum	ND	ug/L	5.0	1.1	10	07/27/17 02:25	07/28/17 19:00	7439-98-7	
Nickel	ND	ug/L	5.0	4.5	10	07/27/17 02:25	07/28/17 19:00	7440-02-0	
Potassium	**15100**	ug/L	500	258	10	07/27/17 02:25	07/31/17 13:42	7440-09-7	M6
Selenium	ND	ug/L	5.0	3.2	10	07/27/17 02:25	07/31/17 13:42	7782-49-2	
Silver	ND	ug/L	5.0	0.80	10	07/27/17 02:25	07/28/17 19:00	7440-22-4	
Sodium	**572000**	ug/L	12500	645	50	07/27/17 02:25	07/31/17 14:17	7440-23-5	M6
Thallium	**0.72J**	ug/L	1.0	0.20	10	07/27/17 02:25	07/28/17 19:00	7440-28-0	
Vanadium	ND	ug/L	5.0	0.70	10	07/27/17 02:25	07/28/17 19:00	7440-62-2	
Zinc	ND	ug/L	50.0	24.0	10	07/27/17 02:25	07/28/17 19:00	7440-66-6	
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	ND	ug/L	500	118	10	07/27/17 03:10	07/28/17 18:44	7439-89-6	
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**727**	mg/L	2.5	2.5	1		07/27/17 21:21		
Total Volatile Solids	**54.0**	mg/L	2.5	2.5	1		07/27/17 21:21		
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity, Total as CaCO3	**48.1**	mg/L	5.0	1.0	1		07/28/17 12:40		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**3450**	mg/L	50.0	50.0	1		07/28/17 13:46		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**7.5**	Std. Units	1.0	0.10	1		07/31/17 13:37		H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	ND	mg/L	0.10	0.10	1		07/31/17 17:42	18496-25-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348882

Sample: NAOH F2 **Lab ID: 92348882002** Collected: 07/24/17 10:50 Received: 07/25/17 07:46 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2550**	mg/L	50.0	25.0	50		07/30/17 15:50	14808-79-8	
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	ND	mg/L	0.050	0.025	1		08/01/17 06:17	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**4.3**	mg/L	1.0	0.50	1		07/29/17 23:45	16887-00-6	
Fluoride	**0.24**	mg/L	0.10	0.050	1		07/29/17 23:45	16984-48-8	

ANALYTICAL RESULTS

Project:	COAL ASH
Pace Project No.:	92348882

Sample: ZVI F2 **Lab ID: 92348882003** Collected: 07/24/17 13:55 Received: 07/25/17 07:46 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Aluminum	**451**	ug/L	100	67.0	10	07/27/17 02:25	07/28/17 19:06	7429-90-5	
Antimony	ND	ug/L	5.0	1.0	10	07/27/17 02:25	07/28/17 19:06	7440-36-0	
Arsenic	**0.77J**	ug/L	1.0	0.50	10	07/27/17 02:25	07/31/17 13:48	7440-38-2	
Barium	**20.7**	ug/L	3.0	1.1	10	07/27/17 02:25	07/28/17 19:06	7440-39-3	
Beryllium	**1.0**	ug/L	1.0	0.20	10	07/27/17 02:25	07/28/17 19:06	7440-41-7	
Cadmium	**1.7**	ug/L	0.80	0.60	10	07/27/17 02:25	07/28/17 19:06	7440-43-9	
Calcium	**496000**	ug/L	2000	1030	10	07/27/17 02:25	07/28/17 19:06	7440-70-2	
Chromium	ND	ug/L	5.0	1.0	10	07/27/17 02:25	07/31/17 13:48	7440-47-3	
Cobalt	**200**	ug/L	1.0	0.10	10	07/27/17 02:25	07/28/17 19:06	7440-48-4	
Copper	ND	ug/L	5.0	1.2	10	07/27/17 02:25	07/28/17 19:06	7440-50-8	
Iron	**622000**	ug/L	5000	1180	100	07/27/17 02:25	07/31/17 14:23	7439-89-6	
Lead	ND	ug/L	1.0	0.80	10	07/27/17 02:25	07/28/17 19:06	7439-92-1	
Lithium	**107**	ug/L	25.0	0.70	10	07/27/17 02:25	07/28/17 19:06	7439-93-2	
Magnesium	**28200**	ug/L	100	17.0	10	07/27/17 02:25	07/28/17 19:06	7439-95-4	
Manganese	**28300**	ug/L	50.0	19.0	100	07/27/17 02:25	07/31/17 14:23	7439-96-5	
Molybdenum	ND	ug/L	5.0	1.1	10	07/27/17 02:25	07/28/17 19:06	7439-98-7	
Nickel	**65.2**	ug/L	5.0	4.5	10	07/27/17 02:25	07/28/17 19:06	7440-02-0	
Potassium	**16900**	ug/L	500	258	10	07/27/17 02:25	07/31/17 13:48	7440-09-7	
Selenium	**10.2**	ug/L	5.0	3.2	10	07/27/17 02:25	07/31/17 13:48	7782-49-2	
Silver	ND	ug/L	5.0	0.80	10	07/27/17 02:25	07/28/17 19:06	7440-22-4	
Sodium	**12600**	ug/L	2500	129	10	07/27/17 02:25	07/31/17 13:48	7440-23-5	
Thallium	ND	ug/L	1.0	0.20	10	07/27/17 02:25	07/28/17 19:06	7440-28-0	
Vanadium	ND	ug/L	5.0	0.70	10	07/27/17 02:25	07/28/17 19:06	7440-62-2	
Zinc	**745**	ug/L	50.0	24.0	10	07/27/17 02:25	07/28/17 19:06	7440-66-6	
6020 MET ICPMS, Dissolved	Analytical Method: EPA 6020B Preparation Method: EPA 3010A								
Iron, Dissolved	**579000**	ug/L	1000	236	20	07/27/17 03:10	08/01/17 12:31	7439-89-6	
160.4 TVS and 2540B TS	Analytical Method: EPA 160.4								
Total Solids (SM 2540B)	**1920**	mg/L	2.5	2.5	1		07/27/17 21:21		
Total Volatile Solids	**250**	mg/L	2.5	2.5	1		07/27/17 21:21		
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity, Total as CaCO3	ND	mg/L	5.0	1.0	1		07/28/17 12:51		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**3690**	mg/L	50.0	50.0	1		07/28/17 13:47		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**3.7**	Std. Units	1.0	0.10	1		07/31/17 13:37		H6
4500S2D Sulfide Water	Analytical Method: SM 4500-S2D								
Sulfide	ND	mg/L	0.10	0.10	1		07/31/17 17:42	18496-25-8	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92348882

Sample: ZVI F2 **Lab ID: 92348882003** Collected: 07/24/17 13:55 Received: 07/25/17 07:46 Matrix: Water

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**2350**	mg/L	50.0	25.0	50		07/30/17 16:53	14808-79-8	
365.1 Phosphorus, Total	Analytical Method: EPA 365.1								
Phosphorus	**0.044J**	mg/L	0.050	0.025	1		08/01/17 06:18	7723-14-0	
9056 IC anions 28 Days	Analytical Method: EPA 9056A								
Chloride	**4.2**	mg/L	1.0	0.50	1		07/30/17 00:34	16887-00-6	
Fluoride	**0.18**	mg/L	0.10	0.050	1		07/30/17 00:34	16984-48-8	

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348882

QC Batch: 370525
Analysis Method: EPA 6020B
QC Batch Method: EPA 3010A
Analysis Description: 6020 MET
Associated Lab Samples: 92348882001

METHOD BLANK: 2053192
Matrix: Water
Associated Lab Samples: 92348882001

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Aluminum	ug/L	ND	10.0	6.7	07/28/17 17:04	
Antimony	ug/L	ND	0.50	0.10	07/28/17 17:04	
Arsenic	ug/L	ND	0.10	0.050	07/28/17 17:04	
Barium	ug/L	ND	0.30	0.11	07/28/17 17:04	
Beryllium	ug/L	ND	0.10	0.020	07/28/17 17:04	
Cadmium	ug/L	ND	0.080	0.060	07/28/17 17:04	
Calcium	ug/L	ND	200	103	07/28/17 17:04	
Chromium	ug/L	0.12J	0.50	0.10	07/28/17 17:04	
Cobalt	ug/L	ND	0.10	0.010	07/28/17 17:04	
Copper	ug/L	ND	0.50	0.12	07/28/17 17:04	
Iron	ug/L	ND	50.0	11.8	07/28/17 17:04	
Lead	ug/L	ND	0.10	0.080	07/28/17 17:04	
Lithium	ug/L	ND	2.5	0.070	07/28/17 17:04	
Magnesium	ug/L	3.3J	10.0	1.7	07/28/17 17:04	
Manganese	ug/L	ND	0.50	0.19	07/28/17 17:04	
Molybdenum	ug/L	ND	0.50	0.11	07/28/17 17:04	
Nickel	ug/L	ND	0.50	0.45	07/28/17 17:04	
Potassium	ug/L	ND	50.0	25.8	07/28/17 17:04	
Selenium	ug/L	ND	0.50	0.32	07/28/17 17:04	
Silver	ug/L	ND	0.50	0.080	07/28/17 17:04	
Sodium	ug/L	21.7J	250	12.9	07/28/17 17:04	
Thallium	ug/L	ND	0.10	0.020	07/28/17 17:04	
Vanadium	ug/L	ND	0.50	0.070	07/28/17 17:04	
Zinc	ug/L	ND	5.0	2.4	07/28/17 17:04	

LABORATORY CONTROL SAMPLE: 2053193

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum	ug/L	100	93.6	94	80-120	
Antimony	ug/L	100	86.9	87	80-120	
Arsenic	ug/L	100	87.4	87	80-120	
Barium	ug/L	100	87.3	87	80-120	
Beryllium	ug/L	100	86.5	86	80-120	
Cadmium	ug/L	100	87.1	87	80-120	
Calcium	ug/L	1250	1100	88	80-120	
Chromium	ug/L	100	90.4	90	80-120	
Cobalt	ug/L	100	92.7	93	80-120	
Copper	ug/L	100	93.7	94	80-120	
Iron	ug/L	1250	1180	94	80-120	
Lead	ug/L	100	86.1	86	80-120	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348882

LABORATORY CONTROL SAMPLE: 2053193

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Lithium	ug/L	100	86.8	87	80-120	
Magnesium	ug/L	1250	1140	91	80-120	
Manganese	ug/L	100	89.2	89	80-120	
Molybdenum	ug/L	100	87.8	88	80-120	
Nickel	ug/L	100	91.6	92	80-120	
Potassium	ug/L	1250	1150	92	80-120	
Selenium	ug/L	100	83.9	84	80-120	
Silver	ug/L	100	86.7	87	80-120	
Sodium	ug/L	1250	1170	94	80-120	
Thallium	ug/L	100	85.5	86	80-120	
Vanadium	ug/L	100	89.8	90	80-120	
Zinc	ug/L	100	85.1	85	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053194 2053195

Parameter	Units	92348850003 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	ug/L	41200	100	100	37700	38000	-3580	-3190	75-125	1	20	M1
Antimony	ug/L	6.0	100	100	116	127	110	121	75-125	10	20	
Arsenic	ug/L	99.1	100	100	195	200	96	101	75-125	3	20	
Barium	ug/L	582	100	100	630	651	48	69	75-125	3	20	M1
Beryllium	ug/L	5.0	100	100	106	116	101	111	75-125	9	20	
Cadmium	ug/L	3.0	100	100	120	126	117	123	75-125	5	20	
Calcium	ug/L	101000	1250	1250	88800	88200	-943	-991	75-125	1	20	M1
Chromium	ug/L	111	100	100	210	219	99	108	75-125	4	20	
Cobalt	ug/L	14.4	100	100	130	136	115	122	75-125	5	20	
Copper	ug/L	110	100	100	214	221	104	110	75-125	3	20	
Iron	ug/L	25300	1250	1250	24500	25100	-64	-21	75-125	2	20	M1
Lead	ug/L	114	100	100	216	219	102	105	75-125	1	20	
Lithium	ug/L	42.4	100	100	144	151	101	109	75-125	5	20	
Magnesium	ug/L	11300	1250	1250	11500	11400	14	5	75-125	1	20	M1
Manganese	ug/L	153	100	100	247	255	94	102	75-125	3	20	
Molybdenum	ug/L	121	100	100	219	234	98	112	75-125	6	20	
Nickel	ug/L	54.3	100	100	165	172	111	118	75-125	4	20	
Potassium	ug/L	23500	1250	1250	21700	21900	-146	-131	75-125	1	20	M1
Selenium	ug/L	23.9	100	100	126	131	102	108	75-125	4	20	
Silver	ug/L	0.58J	100	100	112	120	111	120	75-125	7	20	
Sodium	ug/L	84900	1250	1250	76100	75000	-707	-790	75-125	1	20	M1
Thallium	ug/L	2.5	100	100	115	120	113	117	75-125	4	20	
Vanadium	ug/L	206	100	100	296	301	89	95	75-125	2	20	
Zinc	ug/L	275	100	100	367	378	92	103	75-125	3	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348882

QC Batch: 370699 Analysis Method: EPA 6020B
QC Batch Method: EPA 3010A Analysis Description: 6020 MET
Associated Lab Samples: 92348882002, 92348882003

METHOD BLANK: 2054178 Matrix: Water
Associated Lab Samples: 92348882002, 92348882003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Aluminum	ug/L	ND	10.0	6.7	07/28/17 18:50	
Antimony	ug/L	ND	0.50	0.10	07/28/17 18:50	
Arsenic	ug/L	ND	0.10	0.050	07/31/17 16:11	
Barium	ug/L	ND	0.30	0.11	07/28/17 18:50	
Beryllium	ug/L	ND	0.10	0.020	07/28/17 18:50	
Cadmium	ug/L	ND	0.080	0.060	07/28/17 18:50	
Calcium	ug/L	ND	200	103	07/28/17 18:50	
Chromium	ug/L	ND	0.50	0.10	07/31/17 16:11	
Cobalt	ug/L	0.019J	0.10	0.010	07/28/17 18:50	
Copper	ug/L	0.25J	0.50	0.12	07/31/17 13:38	
Iron	ug/L	ND	50.0	11.8	07/28/17 18:50	
Lead	ug/L	ND	0.10	0.080	07/28/17 18:50	
Lithium	ug/L	ND	2.5	0.070	07/28/17 18:50	
Magnesium	ug/L	ND	10.0	1.7	07/31/17 16:11	
Manganese	ug/L	ND	0.50	0.19	07/31/17 16:11	
Molybdenum	ug/L	ND	0.50	0.11	07/28/17 18:50	
Nickel	ug/L	ND	0.50	0.45	07/28/17 18:50	
Potassium	ug/L	ND	50.0	25.8	07/31/17 16:11	
Selenium	ug/L	ND	0.50	0.32	07/31/17 16:11	
Silver	ug/L	ND	0.50	0.080	07/28/17 18:50	
Sodium	ug/L	14.7J	250	12.9	07/31/17 16:11	
Thallium	ug/L	ND	0.10	0.020	07/28/17 18:50	
Vanadium	ug/L	ND	0.50	0.070	07/28/17 18:50	
Zinc	ug/L	ND	5.0	2.4	07/28/17 18:50	

LABORATORY CONTROL SAMPLE: 2054179

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum	ug/L	100	101	101	80-120	
Antimony	ug/L	100	100	100	80-120	
Arsenic	ug/L	100	99.3	99	80-120	
Barium	ug/L	100	98.4	98	80-120	
Beryllium	ug/L	100	94.2	94	80-120	
Cadmium	ug/L	100	101	101	80-120	
Calcium	ug/L	1250	1180	95	80-120	
Chromium	ug/L	100	102	102	80-120	
Cobalt	ug/L	100	104	104	80-120	
Copper	ug/L	100	105	105	80-120	
Iron	ug/L	1250	1300	104	80-120	
Lead	ug/L	100	97.1	97	80-120	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348882

LABORATORY CONTROL SAMPLE: 2054179

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Lithium	ug/L	100	94.3	94	80-120	
Magnesium	ug/L	1250	1310	104	80-120	
Manganese	ug/L	100	104	104	80-120	
Molybdenum	ug/L	100	102	102	80-120	
Nickel	ug/L	100	103	103	80-120	
Potassium	ug/L	1250	1310	105	80-120	
Selenium	ug/L	100	96.9	97	80-120	
Silver	ug/L	100	100	100	80-120	
Sodium	ug/L	1250	1280	102	80-120	
Thallium	ug/L	100	98.9	99	80-120	
Vanadium	ug/L	100	99.8	100	80-120	
Zinc	ug/L	100	97.9	98	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2054180 2054181

Parameter	Units	92348882002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	ug/L	77.8J	100	100	180	158	102	80	75-125	13	20	
Antimony	ug/L	ND	100	100	109	103	109	102	75-125	6	20	
Arsenic	ug/L	ND	100	100	96.2	104	96	104	75-125	8	20	
Barium	ug/L	9.9	100	100	116	113	106	103	75-125	2	20	
Beryllium	ug/L	ND	100	100	101	96.2	101	96	75-125	5	20	
Cadmium	ug/L	ND	100	100	109	107	109	106	75-125	2	20	
Calcium	ug/L	486000	1250	1250	525000	482000	3120	-362	75-125	9	20	M6
Chromium	ug/L	1.2J	100	100	98.8	105	98	104	75-125	6	20	
Cobalt	ug/L	6.3	100	100	119	115	113	109	75-125	4	20	
Copper	ug/L	ND	100	100	113	111	113	110	75-125	2	20	
Iron	ug/L	762	1250	1250	2290	2130	122	109	75-125	7	20	
Lead	ug/L	ND	100	100	108	106	108	106	75-125	2	20	
Lithium	ug/L	99.0	100	100	222	198	123	99	75-125	11	20	
Magnesium	ug/L	23200	1250	1250	27500	23700	348	40	75-125	15	20	M6
Manganese	ug/L	8470	100	100	9350	8370	881	-100	75-125	11	20	M6
Molybdenum	ug/L	ND	100	100	113	106	113	106	75-125	6	20	
Nickel	ug/L	ND	100	100	116	111	112	107	75-125	4	20	
Potassium	ug/L	15100	1250	1250	17300	17200	180	173	75-125	1	20	M6
Selenium	ug/L	ND	100	100	96.4	99.7	96	100	75-125	3	20	
Silver	ug/L	ND	100	100	104	99.8	104	100	75-125	4	20	
Sodium	ug/L	572000	1250	1250	603000	554000	2490	-1420	75-125	8	20	M6
Thallium	ug/L	0.72J	100	100	109	107	108	106	75-125	2	20	
Vanadium	ug/L	ND	100	100	111	110	111	110	75-125	1	20	
Zinc	ug/L	ND	100	100	115	105	111	101	75-125	9	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348882

QC Batch: 370526 Analysis Method: EPA 6020B
QC Batch Method: EPA 3010A Analysis Description: 6020 MET Dissolved
Associated Lab Samples: 92348882001, 92348882002, 92348882003

METHOD BLANK: 2053196 Matrix: Water
Associated Lab Samples: 92348882001, 92348882002, 92348882003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Iron, Dissolved	ug/L	ND	50.0	11.8	07/28/17 18:11	

LABORATORY CONTROL SAMPLE: 2053197

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Iron, Dissolved	ug/L	1250	1440	115	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053198 2053199

Parameter	Units	92348734001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Iron, Dissolved	ug/L	370000	1250	1250	335000	345000	-2810	-1970	75-125	3	20	M6

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348882

QC Batch: 370701
Analysis Method: EPA 160.4
QC Batch Method: EPA 160.4
Analysis Description: 160.4 TVS and 2540B TS
Associated Lab Samples: 92348882001, 92348882002, 92348882003

METHOD BLANK: 2054185
Matrix: Water
Associated Lab Samples: 92348882001, 92348882002, 92348882003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Solids (SM 2540B)	mg/L	ND	2.5	2.5	07/27/17 21:21	
Total Volatile Solids	mg/L	ND	2.5	2.5	07/27/17 21:21	

LABORATORY CONTROL SAMPLE: 2054186

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Solids (SM 2540B)	mg/L	500	520	104	90-110	

SAMPLE DUPLICATE: 2054187

Parameter	Units	92348734007 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Solids (SM 2540B)	mg/L	3920	3920	0	10	
Total Volatile Solids	mg/L	630	540	15	10	D6

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348882

QC Batch: 370727
Analysis Method: SM 2320B
QC Batch Method: SM 2320B
Analysis Description: 2320B Alkalinity
Associated Lab Samples: 92348882001, 92348882002, 92348882003

METHOD BLANK: 2054283
Matrix: Water
Associated Lab Samples: 92348882001, 92348882002, 92348882003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Alkalinity, Total as CaCO3	mg/L	ND	5.0	1.0	07/28/17 09:46	

LABORATORY CONTROL SAMPLE: 2054284

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Alkalinity, Total as CaCO3	mg/L	50	47.6	95	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2054285 2054286

Parameter	Units	92348772001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Alkalinity, Total as CaCO3	mg/L	83.8	50	50	130	125	92	83	80-120	3	25	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2054287 2054288

Parameter	Units	92348902001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Alkalinity, Total as CaCO3	mg/L	150	50	50	200	202	101	104	80-120	1	25	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project:	COAL ASH
Pace Project No.:	92348882

QC Batch: 370998　　Analysis Method: SM 2540C

QC Batch Method: SM 2540C　　Analysis Description: 2540C Total Dissolved Solids

Associated Lab Samples: 92348882001, 92348882002, 92348882003

METHOD BLANK: 2055648　　Matrix: Water

Associated Lab Samples: 92348882001, 92348882002, 92348882003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Dissolved Solids	mg/L	ND	25.0	25.0	07/28/17 13:36	

LABORATORY CONTROL SAMPLE: 2055649

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Dissolved Solids	mg/L	250	236	94	90-110	

SAMPLE DUPLICATE: 2055650

Parameter	Units	92348842001 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Dissolved Solids	mg/L	464	472	2	5	

SAMPLE DUPLICATE: 2055651

Parameter	Units	92348842011 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Dissolved Solids	mg/L	609	604	1	5	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348882

QC Batch: 371179
Analysis Method: SM 4500-H+B
QC Batch Method: SM 4500-H+B
Analysis Description: 4500H+B pH
Associated Lab Samples: 92348882001, 92348882002, 92348882003

SAMPLE DUPLICATE: 2056621

Parameter	Units	92348882001 Result	Dup Result	RPD	Max RPD	Qualifiers
pH at 25 Degrees C	Std. Units	4.3	4.3	0	10	H6

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348882

QC Batch: 370914
Analysis Method: SM 4500-S2D
QC Batch Method: SM 4500-S2D
Analysis Description: 4500S2D Sulfide Water
Associated Lab Samples: 92348882001, 92348882002, 92348882003

METHOD BLANK: 2055355
Matrix: Water
Associated Lab Samples: 92348882001, 92348882002, 92348882003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Sulfide	mg/L	ND	0.10	0.10	07/31/17 17:42	

LABORATORY CONTROL SAMPLE: 2055356

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Sulfide	mg/L	.5	0.52	105	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2055357 2055358

Parameter	Units	92348842001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Sulfide	mg/L	ND	.5	.5	0.30	0.30	60	60	80-120	0	10	M1

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2055359 2055360

Parameter	Units	92348842011 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Sulfide	mg/L	ND	.5	.5	0.44	0.45	88	88	80-120	0	10	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348882

QC Batch: 370558
Analysis Method: EPA 300.0
QC Batch Method: EPA 300.0
Analysis Description: 300.0 IC Anions
Associated Lab Samples: 92348882001, 92348882002, 92348882003

METHOD BLANK: 2053285
Matrix: Water
Associated Lab Samples: 92348882001, 92348882002, 92348882003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Sulfate	mg/L	ND	1.0	0.50	07/30/17 13:26	

LABORATORY CONTROL SAMPLE: 2053286

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Sulfate	mg/L	50	54.4	109	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053287 2053288

Parameter	Units	92348833001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Sulfate	mg/L	5760	50	50	5770	5740	33	-32	90-110	1	10	M6

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053289 2053290

Parameter	Units	92348730008 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Sulfate	mg/L	5.2	50	50	75.1	75.1	140	140	90-110	0	10	M1

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project:	COAL ASH
Pace Project No.:	92348882

QC Batch:	370899	Analysis Method:	EPA 365.1
QC Batch Method:	EPA 365.1	Analysis Description:	365.1 Phosphorus, Total

Associated Lab Samples: 92348882001, 92348882002, 92348882003

METHOD BLANK: 2055283 Matrix: Water

Associated Lab Samples: 92348882001, 92348882002, 92348882003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Phosphorus	mg/L	ND	0.050	0.025	08/01/17 06:12	

LABORATORY CONTROL SAMPLE: 2055284

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Phosphorus	mg/L	2.5	2.6	103	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2055285 2055286

Parameter	Units	92348136001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Phosphorus	mg/L	0.56	2.5	2.5	3.2	3.1	105	101	90-110	3	10	

MATRIX SPIKE SAMPLE: 2055287

Parameter	Units	92349000003 Result	Spike Conc.	MS Result	MS % Rec	% Rec Limits	Qualifiers
Phosphorus	mg/L	ND	2.5	2.5	100	90-110	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92348882

QC Batch: 370559 Analysis Method: EPA 9056A
QC Batch Method: EPA 9056A Analysis Description: 9056 IC anions 28 Days
Associated Lab Samples: 92348882001, 92348882002, 92348882003

METHOD BLANK: 2053291 Matrix: Water
Associated Lab Samples: 92348882001, 92348882002, 92348882003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Chloride	mg/L	ND	1.0	0.50	07/29/17 17:42	
Fluoride	mg/L	ND	0.10	0.050	07/29/17 17:42	

LABORATORY CONTROL SAMPLE: 2053292

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Chloride	mg/L	50	52.1	104	90-110	
Fluoride	mg/L	2.5	2.7	106	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053293 2053294

Parameter	Units	92348734001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Chloride	mg/L	2.9	50	50	55.8	55.8	106	106	90-110	0	10	
Fluoride	mg/L	0.40	2.5	2.5	2.8	2.8	96	96	90-110	1	10	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2053295 2053296

Parameter	Units	92348882002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Chloride	mg/L	4.3	50	50	57.2	57.4	106	106	90-110	0	10	
Fluoride	mg/L	0.24	2.5	2.5	2.8	2.8	102	101	90-110	1	10	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALIFIERS

Project:	COAL ASH
Pace Project No.:	92348882

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to dilution of the sample aliquot.

ND - Not Detected at or above adjusted reporting limit.

TNTC - Too Numerous To Count

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

PQL - Practical Quantitation Limit.

RL - Reporting Limit.

S - Surrogate

1,2-Diphenylhydrazine decomposes to and cannot be separated from Azobenzene using Method 8270. The result for each analyte is a combined concentration.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

Acid preservation may not be appropriate for 2 Chloroethylvinyl ether.

A separate vial preserved to a pH of 4-5 is recommended in SW846 Chapter 4 for the analysis of Acrolein and Acrylonitrile by EPA Method 8260.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

TNI - The NELAC Institute.

LABORATORIES

PASI-A	Pace Analytical Services - Asheville

ANALYTE QUALIFIERS

B	Analyte was detected in the associated method blank.
D6	The precision between the sample and sample duplicate exceeded laboratory control limits.
H6	Analysis initiated outside of the 15 minute EPA required holding time.
M1	Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.
M6	Matrix spike and Matrix spike duplicate recovery not evaluated against control limits due to sample dilution.

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: COAL ASH
Pace Project No.: 92348882

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
92348882001	**FB F2**	EPA 3010A	370525	EPA 6020B	370766
92348882002	**NAOH F2**	EPA 3010A	370699	EPA 6020B	370768
92348882003	**ZVI F2**	EPA 3010A	370699	EPA 6020B	370768
92348882001	**FB F2**	EPA 3010A	370526	EPA 6020B	370767
92348882002	**NAOH F2**	EPA 3010A	370526	EPA 6020B	370767
92348882003	**ZVI F2**	EPA 3010A	370526	EPA 6020B	370767
92348882001	**FB F2**	EPA 160.4	370701		
92348882002	**NAOH F2**	EPA 160.4	370701		
92348882003	**ZVI F2**	EPA 160.4	370701		
92348882001	**FB F2**	SM 2320B	370727		
92348882002	**NAOH F2**	SM 2320B	370727		
92348882003	**ZVI F2**	SM 2320B	370727		
92348882001	**FB F2**	SM 2540C	370998		
92348882002	**NAOH F2**	SM 2540C	370998		
92348882003	**ZVI F2**	SM 2540C	370998		
92348882001	**FB F2**	SM 4500-H+B	371179		
92348882002	**NAOH F2**	SM 4500-H+B	371179		
92348882003	**ZVI F2**	SM 4500-H+B	371179		
92348882001	**FB F2**	SM 4500-S2D	370914		
92348882002	**NAOH F2**	SM 4500-S2D	370914		
92348882003	**ZVI F2**	SM 4500-S2D	370914		
92348882001	**FB F2**	EPA 300.0	370558		
92348882002	**NAOH F2**	EPA 300.0	370558		
92348882003	**ZVI F2**	EPA 300.0	370558		
92348882001	**FB F2**	EPA 365.1	370899		
92348882002	**NAOH F2**	EPA 365.1	370899		
92348882003	**ZVI F2**	EPA 365.1	370899		
92348882001	**FB F2**	EPA 9056A	370559		
92348882002	**NAOH F2**	EPA 9056A	370559		
92348882003	**ZVI F2**	EPA 9056A	370559		

Pace Analytical®	Document Name: **Sample Condition Upon Receipt(SCUR)**	Document Revised: Sept. 21, 2016 Page 1 of 2
	Document No.: **F-CAR-CS-033-Rev.01**	Issuing Authority: Pace Quality Office

Laboratory receiving samples:

Asheville ☐ **Eden** ☐ **Greenwood** ☐ **Huntersville** ☑ **Raleigh** ☐ **Mechanicsville** ☐

Sample Condition Upon Receipt

Client Name: Redox Tech LLC

Project #:

WO# : 92348882

92348882

Courier: ☐ Commercial ☐ Fed Ex ☑ Pace ☐ UPS ☐ USPS ☐ Other:____ ☐ Client

Custody Seal Present? ☐ Yes ☑ No **Seals Intact?** ☐ Yes ☑ No

Date/Initials Person Examining Contents: LD 7-25-17

Packing Material: ☐ Bubble Wrap ☑ Bubble Bags ☐ None ☑ Other: Ziploc

Thermometer: ☑ IR Gun ID: T1603 LD 7-25-17

Type of Ice: ☑ Wet ☐ Blue ☐ None ☑ Samples on ice, cooling process has begun

Correction Factor: **Cooler Temp Corrected (°C):** 5.8

Biological Tissue Frozen? ☐ Yes ☑ No ☐ N/A

Temp should be above freezing to 6°C

USDA Regulated Soil (☑ N/A, water sample)

Did samples originate in a quarantine zone within the United States: CA, NY, or SC (check maps)? ☐ Yes ☑ No

Did samples originate from a foreign source (internationally, including Hawaii and Puerto Rico)? ☐ Yes ☑ No

				Comments/Discrepancy:
Chain of Custody Present?	☑ Yes	☐ No	☐ N/A	1.
Samples Arrived within Hold Time?	☑ Yes	☐ No	☐ N/A	2.
Short Hold Time Analysis (<72 hr.)?	☐ Yes	☑ No	☐ N/A	3.
Rush Turn Around Time Requested?	☑ Yes	☐ No	☐ N/A	4.
Sufficient Volume?	☑ Yes	☐ No	☐ N/A	5.
Correct Containers Used?	☑ Yes	☐ No	☐ N/A	6.
-Pace Containers Used?	☑ Yes	☐ No	☐ N/A	
Containers Intact?	☑ Yes	☐ No	☐ N/A	7.
Samples Field Filtered?	☐ Yes	☑ No	☐ N/A	8. Note if sediment is visible in the dissolved container
Sample Labels Match COC?	☑ Yes	☐ No	☐ N/A	9.
-Includes Date/Time/ID/Analysis Matrix: WT				
Headspace in VOA Vials (>5-6mm)?	☐ Yes	☐ No	☑ N/A	10.
Trip Blank Present?	☐ Yes	☐ No	☑ N/A	11.
Trip Blank Custody Seals Present?	☐ Yes	☐ No	☑ N/A	

CLIENT NOTIFICATION/RESOLUTION

Field Data Required? ☐ Yes ☐ No

Person Contacted: Joe Rossabi Date/Time: 7/25

Comments/Sample Discrepancy: Samples logged in for parameters and methods based on analytical table provided by client, not for parameters listed on COC.

Project Manager SCURF Review: NMG **Date:** 7/25/17

Project Manager SRF Review: NMG **Date:** 7/25/17

Note: Whenever there is a discrepancy affecting North Carolina compliance samples, a copy of this form will be sent to the North Carolina DEHNR Certification Office (i.e. Out of hold, incorrect preservative, out of temp, incorrect containers)

Pace Analytical

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page : 1 Of 1

Section A
Required Client Information:

Company: Redox Tech, LLC
Address: 200 Quade Dr
Cary, NC 27513
Email: rossabi@redox-tech.com
Phone: 919 678-0140 Fax 919 678-0150
Requested Due Date: 5 days

Section B
Required Project Information:

Report To: Joe Rossabi
Copy To:
Purchase Order #:
Project Name: Coal Ash
Project #:

Section C
Invoice Information:

Attention:
Company Name:
Address:
Pace Quote:
Pace Project Manager: taylor.ezell@pacelabs.com,
Pace Profile #: 8670-1

Regulatory Agency
State / Location: NC

Requested Analysis Filtered (Y/N)

92348882

SAMPLE ID
One Character per box.
(A-Z, 0-9 / , -)
Sample Ids must be unique

MATRIX	CODE
Drinking Water	DW
Water	WT
Waste Water	WW
Product	P
Soil/Solid	SL
Oil	OL
Wipe	WP
Air	AR
Other	OT
Tissue	TS

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED START DATE	COLLECTED START TIME	COLLECTED END DATE	COLLECTED END TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Unpreserved	H2SO4	HNO3	HCl	NaOH	Na2S2O3	Methanol	Other	Analyses Test Y/N	Alkalinity, TDS, TS	Chloride, Fluoride	Ignitability	Total Phosphorus	Sulfide	Total Metals							Residual Chlorine (Y/N)	
1	FB F2			7/24/17	8:42				7	4	1	1		1					✓	✓	✓	✓	✓	✓								001
2	NaOH F2			7/24/17	10:50				7	4	1	1		1					✓	✓	✓	✓	✓	✓								002
3	ZVI F2			7/24/17	13:53				7	4	1	1		1					✓	✓	✓	✓	✓	✓								003
4																																
5																																
6																																
7																																
8																																
9																																
10																																
11																																
12																																

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	TEMP in C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)
	Redox Tech	7/24/17	3:30pm		7-24-17	1530	22	Y	N	Y
		7/25/17	0746	pace	7/25/17	0746				
	pace	7/25/17	01130		7-25-17	1130	5.8	Y	N	Y

SAMPLE CONDITIONS

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: ROSSABI
SIGNATURE of SAMPLER:
DATE Signed: 7/24/17

***Check mark top half of box if pH and/or dechlorination is verified and within the acceptance range for preservation samples.**

****Bottom half of box is to list number of bottles**

Project # WO#:92348882

PM: PTE Due Date: 08/01/17

CLIENT: 92-RedoxTech

Item#	BP4U-125 mL Plastic Unpreserved (N/A) (Cl-)	BP3U-250 mL Plastic Unpreserved (N/A)	BP2U-500 mL Plastic Unpreserved (N/A)	BP1U-1 liter Plastic Unpreserved (N/A)	BP3S-250 mL Plastic H2SO4 (pH < 2) (Cl-)	BP3N-250 mL plastic HNO3 (pH < 2)	BP3Z-250 mL Plastic ZN Acetate & NaOH (>9)	BP3C-250 mL Plastic NaOH (pH > 12) (Cl-)	WGFU-Wide-mouthed Glass jar Unpreserved	AG1U-1 liter Amber Unpreserved (N/A) (Cl-)	AG1H-1 liter Amber HCl (pH < 2)	AG3U-250 mL Amber Unpreserved (N/A) (Cl-)	AG1S-1 liter Amber H2SO4 (pH < 2)	AG3S-250 mL Amber H2SO4 (pH < 2)	AG3A(DG3A)-250 mL Amber NH4Cl (N/A)(Cl-)	DG9H-40 mL VOA HCl (N/A)	VG9T-40 mL VOA Na2S2O3 (N/A)	VG9U-40 mL VOA Unp (N/A)	DG9P-40 mL VOA H3PO4 (N/A)	VOAK (6 vials per kit)-5035 kit (N/A)	V/GK (3 vials per kit)-VPH/Gas kit (N/A)	SP5T-125 mL Sterile Plastic (N/A – lab)	SP2T-250 mL Sterile Plastic (N/A – lab)		BP3A-250 mL Plastic (NH2)2SO4 (9.3-9.7)	Cubitainer	VSGU-20 mL Scintillation vials **(N/A)**	GN
1	1	1		2	✓ 1	✓ 1	✓ 1																					
2	1	1		2	✓ 1	✓ 1	✓ 1																					
3	1	1		2	✓ 1	✓ 1	✓ 1																					
4																												
5																												
6																												
7																												
8																												
9																												
10																												
11																												
12																												

pH Adjustment Log for Preserved Samples

Sample ID	Type of Preservative	pH upon receipt	Date preservation adjusted	Time preservation adjusted	Amount of Preservative added	Lot #

Pace Analytical Services, LLC
9800 Kincey Ave. Suite 100
Huntersville, NC 28078
(704)875-9092

August 06, 2017

Joe Rassabi

200 Quade Drive
Cary, NC 27513

RE: Project: COAL ASH
Pace Project No.: 92349301

Dear Joe Rassabi:

Enclosed are the analytical results for sample(s) received by the laboratory on July 27, 2017. The results relate only to the samples included in this report. Results reported herein conform to the most current, applicable TNI/NELAC standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Taylor Ezell
taylor.ezell@pacelabs.com
(704)875-9092
Project Manager

Enclosures

cc: John Haselow, Redox Tech, LLC

CERTIFICATIONS

Project:	COAL ASH
Pace Project No.:	92349301

Asheville Certification IDs

2225 Riverside Drive, Asheville, NC 28804
Florida/NELAP Certification #: E87648
Massachusetts Certification #: M-NC030
North Carolina Drinking Water Certification #: 37712
North Carolina Wastewater Certification #: 40
South Carolina Certification #: 99030001
Virginia/VELAP Certification #: 460222

SAMPLE SUMMARY

Project: COAL ASH
Pace Project No.: 92349301

Lab ID	Sample ID	Matrix	Date Collected	Date Received
92349301001	**FBS 5.79G**	Solid	07/26/17 09:47	07/27/17 12:42
92349301002	**NAOHS 10.41G**	Solid	07/26/17 10:32	07/27/17 12:42
92349301003	**EB 29.38G**	Solid	07/26/17 10:34	07/27/17 12:42
92349301004	**ZVI 34.37G**	Solid	07/26/17 09:58	07/27/17 12:42
92349301005	**AMS 3.40G**	Solid	07/26/17 10:17	07/27/17 12:42

SAMPLE ANALYTE COUNT

Project: COAL ASH
Pace Project No.: 92349301

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
92349301001	**FBS 5.79G**	EPA 6010	SH1	23	PASI-A
92349301002	**NAOHS 10.41G**	EPA 6010	SH1	23	PASI-A
92349301003	**EB 29.38G**	EPA 6010	SH1	23	PASI-A
92349301004	**ZVI 34.37G**	EPA 6010	SH1	23	PASI-A
92349301005	**AMS 3.40G**	EPA 6010	SH1	23	PASI-A

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92349301

Sample: FBS 5.79G **Lab ID: 92349301001** Collected: 07/26/17 09:47 Received: 07/27/17 12:42 Matrix: Solid

Results reported on a "wet-weight" basis

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**50000**	mg/kg	133	66.7	20	08/02/17 20:05	08/05/17 14:47	7429-90-5	D3
Antimony	ND	mg/kg	6.7	5.2	20	08/02/17 20:05	08/05/17 14:47	7440-36-0	D3
Arsenic	**8.9J**	mg/kg	13.3	6.7	20	08/02/17 20:05	08/05/17 14:47	7440-38-2	D3
Barium	ND	mg/kg	6.7	3.3	20	08/02/17 20:05	08/05/17 14:47	7440-39-3	D3
Beryllium	**2.5**	mg/kg	1.3	0.67	20	08/02/17 20:05	08/05/17 14:47	7440-41-7	D3
Cadmium	ND	mg/kg	1.3	0.67	20	08/02/17 20:05	08/05/17 14:47	7440-43-9	D3
Calcium	**1510**	mg/kg	133	66.7	20	08/02/17 20:05	08/05/17 14:47	7440-70-2	D3
Chromium	**97.1**	mg/kg	6.7	3.3	20	08/02/17 20:05	08/05/17 14:47	7440-47-3	D3
Cobalt	**98.5**	mg/kg	6.7	3.3	20	08/02/17 20:05	08/05/17 14:47	7440-48-4	D3
Copper	**211**	mg/kg	6.7	3.3	20	08/02/17 20:05	08/05/17 14:47	7440-50-8	D3
Iron	**173000**	mg/kg	333	167	50	08/02/17 20:05	08/05/17 19:58	7439-89-6	D3
Lead	**18.0**	mg/kg	6.7	3.3	20	08/02/17 20:05	08/05/17 14:47	7439-92-1	D3
Magnesium	**186**	mg/kg	133	3.3	20	08/02/17 20:05	08/05/17 14:47	7439-95-4	D3
Manganese	**499**	mg/kg	6.7	3.3	20	08/02/17 20:05	08/05/17 14:47	7439-96-5	D3
Molybdenum	**21.2**	mg/kg	6.7	3.3	20	08/02/17 20:05	08/05/17 14:47	7439-98-7	D3
Nickel	**101**	mg/kg	6.7	3.3	20	08/02/17 20:05	08/05/17 14:47	7440-02-0	D3
Potassium	ND	mg/kg	6670	6670	20	08/02/17 20:05	08/05/17 14:47	7440-09-7	D3
Selenium	ND	mg/kg	13.3	6.7	20	08/02/17 20:05	08/05/17 14:47	7782-49-2	D3
Silver	ND	mg/kg	6.7	3.3	20	08/02/17 20:05	08/05/17 14:47	7440-22-4	D3
Sodium	ND	mg/kg	6670	3330	20	08/02/17 20:05	08/05/17 14:47	7440-23-5	D3
Thallium	ND	mg/kg	13.3	6.7	20	08/02/17 20:05	08/05/17 14:47	7440-28-0	D3
Vanadium	**18.3**	mg/kg	6.7	3.3	20	08/02/17 20:05	08/05/17 14:47	7440-62-2	D3
Zinc	**3180**	mg/kg	13.3	6.7	20	08/02/17 20:05	08/05/17 14:47	7440-66-6	D3

ANALYTICAL RESULTS

Project:	COAL ASH
Pace Project No.:	92349301

Sample: NAOHS 10.41G **Lab ID: 92349301002** Collected: 07/26/17 10:32 Received: 07/27/17 12:42 Matrix: Solid

Results reported on a "wet-weight" basis

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**10500**	mg/kg	110	54.9	20	08/02/17 20:05	08/05/17 17:49	7429-90-5	D3
Antimony	ND	mg/kg	5.5	4.3	20	08/02/17 20:05	08/05/17 17:49	7440-36-0	D3
Arsenic	**7.7J**	mg/kg	11.0	5.5	20	08/02/17 20:05	08/05/17 17:49	7440-38-2	D3
Barium	ND	mg/kg	5.5	2.7	20	08/02/17 20:05	08/05/17 17:49	7440-39-3	D3
Beryllium	**1.9**	mg/kg	1.1	0.55	20	08/02/17 20:05	08/05/17 17:49	7440-41-7	D3
Cadmium	ND	mg/kg	1.1	0.55	20	08/02/17 20:05	08/05/17 17:49	7440-43-9	D3
Calcium	**1680**	mg/kg	110	54.9	20	08/02/17 20:05	08/05/17 17:49	7440-70-2	D3
Chromium	ND	mg/kg	5.5	2.7	20	08/02/17 20:05	08/05/17 17:49	7440-47-3	D3
Cobalt	**61.7**	mg/kg	5.5	2.7	20	08/02/17 20:05	08/05/17 17:49	7440-48-4	D3
Copper	**9.3**	mg/kg	5.5	2.7	20	08/02/17 20:05	08/05/17 17:49	7440-50-8	D3
Iron	**69900**	mg/kg	110	54.9	20	08/02/17 20:05	08/05/17 17:49	7439-89-6	D3
Lead	**10.1**	mg/kg	5.5	2.7	20	08/02/17 20:05	08/05/17 17:49	7439-92-1	D3
Magnesium	**534**	mg/kg	110	2.7	20	08/02/17 20:05	08/05/17 17:49	7439-95-4	D3
Manganese	**3140**	mg/kg	5.5	2.7	20	08/02/17 20:05	08/05/17 17:49	7439-96-5	D3
Molybdenum	ND	mg/kg	5.5	2.7	20	08/02/17 20:05	08/05/17 17:49	7439-98-7	D3
Nickel	**33.3**	mg/kg	5.5	2.7	20	08/02/17 20:05	08/05/17 17:49	7440-02-0	D3
Potassium	ND	mg/kg	5490	5490	20	08/02/17 20:05	08/05/17 17:49	7440-09-7	D3
Selenium	ND	mg/kg	11.0	5.5	20	08/02/17 20:05	08/05/17 17:49	7782-49-2	D3
Silver	ND	mg/kg	5.5	2.7	20	08/02/17 20:05	08/05/17 17:49	7440-22-4	D3
Sodium	ND	mg/kg	5490	2750	20	08/02/17 20:05	08/05/17 17:49	7440-23-5	D3
Thallium	ND	mg/kg	11.0	5.5	20	08/02/17 20:05	08/05/17 17:49	7440-28-0	D3
Vanadium	**3.5J**	mg/kg	5.5	2.7	20	08/02/17 20:05	08/05/17 17:49	7440-62-2	D3
Zinc	**288**	mg/kg	11.0	5.5	20	08/02/17 20:05	08/05/17 17:49	7440-66-6	D3

ANALYTICAL RESULTS

Project:	COAL ASH
Pace Project No.:	92349301

Sample: EB 29.38G **Lab ID: 92349301003** Collected: 07/26/17 10:34 Received: 07/27/17 12:42 Matrix: Solid

Results reported on a "wet-weight" basis

6010 MET ICP Analytical Method: EPA 6010 Preparation Method: EPA 3050

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
Aluminum	**5540**	mg/kg	8.6	4.3	1	08/02/17 20:05	08/03/17 13:54	7429-90-5	
Antimony	ND	mg/kg	0.43	0.34	1	08/02/17 20:05	08/03/17 13:54	7440-36-0	
Arsenic	**5.3**	mg/kg	0.86	0.43	1	08/02/17 20:05	08/03/17 13:54	7440-38-2	
Barium	**1.6**	mg/kg	0.43	0.22	1	08/02/17 20:05	08/03/17 13:54	7440-39-3	
Beryllium	**0.71**	mg/kg	0.086	0.043	1	08/02/17 20:05	08/03/17 13:54	7440-41-7	
Cadmium	**0.29**	mg/kg	0.086	0.043	1	08/02/17 20:05	08/03/17 13:54	7440-43-9	
Calcium	**14200**	mg/kg	431	216	50	08/02/17 20:05	08/05/17 15:27	7440-70-2	
Chromium	**3.2**	mg/kg	0.43	0.22	1	08/02/17 20:05	08/03/17 13:54	7440-47-3	
Cobalt	**20.6**	mg/kg	0.43	0.22	1	08/02/17 20:05	08/03/17 13:54	7440-48-4	
Copper	ND	mg/kg	0.43	0.22	1	08/02/17 20:05	08/03/17 13:54	7440-50-8	
Iron	**41800**	mg/kg	431	216	50	08/02/17 20:05	08/05/17 15:27	7439-89-6	
Lead	**5.7**	mg/kg	0.43	0.22	1	08/02/17 20:05	08/03/17 13:54	7439-92-1	
Magnesium	**303000**	mg/kg	431	10.8	50	08/02/17 20:05	08/05/17 15:27	7439-95-4	
Manganese	**2000**	mg/kg	21.6	10.8	50	08/02/17 20:05	08/05/17 15:27	7439-96-5	
Molybdenum	**2.3**	mg/kg	0.43	0.22	1	08/02/17 20:05	08/03/17 13:54	7439-98-7	
Nickel	**12.1**	mg/kg	0.43	0.22	1	08/02/17 20:05	08/03/17 13:54	7440-02-0	
Potassium	ND	mg/kg	431	431	1	08/02/17 20:05	08/03/17 13:54	7440-09-7	
Selenium	ND	mg/kg	0.86	0.43	1	08/02/17 20:05	08/03/17 13:54	7782-49-2	
Silver	**0.24J**	mg/kg	0.43	0.22	1	08/02/17 20:05	08/03/17 13:54	7440-22-4	
Sodium	ND	mg/kg	431	216	1	08/02/17 20:05	08/03/17 13:54	7440-23-5	
Thallium	ND	mg/kg	0.86	0.43	1	08/02/17 20:05	08/03/17 13:54	7440-28-0	
Vanadium	**5.8**	mg/kg	0.43	0.22	1	08/02/17 20:05	08/03/17 13:54	7440-62-2	
Zinc	**121**	mg/kg	0.86	0.43	1	08/02/17 20:05	08/03/17 13:54	7440-66-6	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92349301

Sample: ZVI 34.37G **Lab ID: 92349301004** Collected: 07/26/17 09:58 Received: 07/27/17 12:42 Matrix: Solid

Results reported on a "wet-weight" basis

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**1270**	mg/kg	5.3	2.7	1	08/02/17 20:05	08/03/17 13:58	7429-90-5	
Antimony	**10.6**	mg/kg	0.27	0.21	1	08/02/17 20:05	08/03/17 13:58	7440-36-0	
Arsenic	**9.9**	mg/kg	0.53	0.27	1	08/02/17 20:05	08/03/17 13:58	7440-38-2	
Barium	ND	mg/kg	0.27	0.13	1	08/02/17 20:05	08/03/17 13:58	7440-39-3	
Beryllium	ND	mg/kg	0.053	0.027	1	08/02/17 20:05	08/03/17 13:58	7440-41-7	
Cadmium	ND	mg/kg	0.053	0.027	1	08/02/17 20:05	08/03/17 13:58	7440-43-9	
Calcium	**116**	mg/kg	5.3	2.7	1	08/02/17 20:05	08/03/17 13:58	7440-70-2	
Chromium	**43.8**	mg/kg	0.27	0.13	1	08/02/17 20:05	08/03/17 13:58	7440-47-3	
Cobalt	**199**	mg/kg	0.27	0.13	1	08/02/17 20:05	08/03/17 13:58	7440-48-4	
Copper	**114**	mg/kg	0.27	0.13	1	08/02/17 20:05	08/03/17 13:58	7440-50-8	
Iron	**434000**	mg/kg	532	266	100	08/02/17 20:05	08/05/17 17:56	7439-89-6	
Lead	**21.8**	mg/kg	0.27	0.13	1	08/02/17 20:05	08/03/17 13:58	7439-92-1	
Magnesium	ND	mg/kg	5.3	0.13	1	08/02/17 20:05	08/03/17 13:58	7439-95-4	
Manganese	**37.4**	mg/kg	0.27	0.13	1	08/02/17 20:05	08/03/17 13:58	7439-96-5	
Molybdenum	**8.9**	mg/kg	0.27	0.13	1	08/02/17 20:05	08/03/17 13:58	7439-98-7	
Nickel	**350**	mg/kg	0.27	0.13	1	08/02/17 20:05	08/03/17 13:58	7440-02-0	
Potassium	ND	mg/kg	266	266	1	08/02/17 20:05	08/03/17 13:58	7440-09-7	
Selenium	ND	mg/kg	0.53	0.27	1	08/02/17 20:05	08/03/17 13:58	7782-49-2	
Silver	**2.7**	mg/kg	0.27	0.13	1	08/02/17 20:05	08/03/17 13:58	7440-22-4	
Sodium	ND	mg/kg	266	133	1	08/02/17 20:05	08/03/17 13:58	7440-23-5	
Thallium	**1.2**	mg/kg	0.53	0.27	1	08/02/17 20:05	08/03/17 13:58	7440-28-0	
Vanadium	**61.0**	mg/kg	0.27	0.13	1	08/02/17 20:05	08/03/17 13:58	7440-62-2	
Zinc	**1.1**	mg/kg	0.53	0.27	1	08/02/17 20:05	08/03/17 13:58	7440-66-6	

ANALYTICAL RESULTS

Project: COAL ASH
Pace Project No.: 92349301

Sample: AMS 3.40G **Lab ID: 92349301005** Collected: 07/26/17 10:17 Received: 07/27/17 12:42 Matrix: Solid

Results reported on a "wet-weight" basis

Parameters	Results	Units	Report Limit	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**17700**	mg/kg	90.9	45.5	10	08/02/17 20:05	08/05/17 17:59	7429-90-5	D3
Antimony	ND	mg/kg	4.5	3.5	10	08/02/17 20:05	08/05/17 17:59	7440-36-0	D3
Arsenic	**8.7J**	mg/kg	9.1	4.5	10	08/02/17 20:05	08/05/17 17:59	7440-38-2	D3
Barium	**13.5**	mg/kg	4.5	2.3	10	08/02/17 20:05	08/05/17 17:59	7440-39-3	D3
Beryllium	**1.9**	mg/kg	0.91	0.45	10	08/02/17 20:05	08/05/17 17:59	7440-41-7	D3
Cadmium	ND	mg/kg	0.91	0.45	10	08/02/17 20:05	08/05/17 17:59	7440-43-9	D3
Calcium	**30600**	mg/kg	90.9	45.5	10	08/02/17 20:05	08/05/17 17:59	7440-70-2	D3
Chromium	**3.7J**	mg/kg	4.5	2.3	10	08/02/17 20:05	08/05/17 17:59	7440-47-3	D3
Cobalt	**9.9**	mg/kg	4.5	2.3	10	08/02/17 20:05	08/05/17 17:59	7440-48-4	D3
Copper	**5.6**	mg/kg	4.5	2.3	10	08/02/17 20:05	08/05/17 17:59	7440-50-8	D3
Iron	**82300**	mg/kg	90.9	45.5	10	08/02/17 20:05	08/05/17 17:59	7439-89-6	D3
Lead	**28.2**	mg/kg	4.5	2.3	10	08/02/17 20:05	08/05/17 17:59	7439-92-1	D3
Magnesium	**857**	mg/kg	90.9	2.3	10	08/02/17 20:05	08/05/17 17:59	7439-95-4	D3
Manganese	**2780**	mg/kg	4.5	2.3	10	08/02/17 20:05	08/05/17 17:59	7439-96-5	D3
Molybdenum	**2.9J**	mg/kg	4.5	2.3	10	08/02/17 20:05	08/05/17 17:59	7439-98-7	D3
Nickel	**6.4**	mg/kg	4.5	2.3	10	08/02/17 20:05	08/05/17 17:59	7440-02-0	D3
Potassium	ND	mg/kg	4550	4550	10	08/02/17 20:05	08/05/17 17:59	7440-09-7	D3
Selenium	ND	mg/kg	9.1	4.5	10	08/02/17 20:05	08/05/17 17:59	7782-49-2	D3
Silver	ND	mg/kg	4.5	2.3	10	08/02/17 20:05	08/05/17 17:59	7440-22-4	D3
Sodium	**7170**	mg/kg	4550	2270	10	08/02/17 20:05	08/05/17 17:59	7440-23-5	D3
Thallium	ND	mg/kg	9.1	4.5	10	08/02/17 20:05	08/05/17 17:59	7440-28-0	D3
Vanadium	**6.3**	mg/kg	4.5	2.3	10	08/02/17 20:05	08/05/17 17:59	7440-62-2	D3
Zinc	**99.6**	mg/kg	9.1	4.5	10	08/02/17 20:05	08/05/17 17:59	7440-66-6	D3

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92349301

QC Batch: 371289 Analysis Method: EPA 6010
QC Batch Method: EPA 3050 Analysis Description: 6010 MET
Associated Lab Samples: 92349301001, 92349301002, 92349301003, 92349301004, 92349301005

METHOD BLANK: 2057126 Matrix: Solid
Associated Lab Samples: 92349301001, 92349301002, 92349301003, 92349301004, 92349301005

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Aluminum	mg/kg	ND	10.0	5.0	08/03/17 13:17	
Antimony	mg/kg	ND	0.50	0.39	08/03/17 13:17	
Arsenic	mg/kg	ND	1.0	0.50	08/03/17 13:17	
Barium	mg/kg	ND	0.50	0.25	08/03/17 13:17	
Beryllium	mg/kg	ND	0.10	0.050	08/03/17 13:17	
Cadmium	mg/kg	ND	0.10	0.050	08/03/17 13:17	
Calcium	mg/kg	ND	10.0	5.0	08/03/17 13:20	
Chromium	mg/kg	ND	0.50	0.25	08/03/17 13:17	
Cobalt	mg/kg	ND	0.50	0.25	08/03/17 13:17	
Copper	mg/kg	ND	0.50	0.25	08/03/17 13:17	
Iron	mg/kg	ND	10.0	5.0	08/03/17 13:17	
Lead	mg/kg	ND	0.50	0.25	08/03/17 13:17	
Magnesium	mg/kg	0.92J	10.0	0.25	08/03/17 13:17	
Manganese	mg/kg	ND	0.50	0.25	08/03/17 13:17	
Molybdenum	mg/kg	ND	0.50	0.25	08/03/17 13:17	
Nickel	mg/kg	ND	0.50	0.25	08/03/17 13:17	
Potassium	mg/kg	ND	500	500	08/03/17 13:17	
Selenium	mg/kg	ND	1.0	0.50	08/03/17 13:17	
Silver	mg/kg	ND	0.50	0.25	08/03/17 13:17	
Sodium	mg/kg	ND	500	250	08/03/17 13:17	
Thallium	mg/kg	ND	1.0	0.50	08/03/17 13:17	
Vanadium	mg/kg	ND	0.50	0.25	08/03/17 13:17	
Zinc	mg/kg	ND	1.0	0.50	08/03/17 13:20	

LABORATORY CONTROL SAMPLE: 2057127

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum	mg/kg	500	596	119	80-120	
Antimony	mg/kg	50	48.3	97	80-120	
Arsenic	mg/kg	50	46.4	93	80-120	
Barium	mg/kg	50	48.9	98	80-120	
Beryllium	mg/kg	50	49.0	98	80-120	
Cadmium	mg/kg	50	47.9	96	80-120	
Calcium	mg/kg	500	498	100	80-120	
Chromium	mg/kg	50	49.0	98	80-120	
Cobalt	mg/kg	50	48.6	97	80-120	
Copper	mg/kg	50	48.3	97	80-120	
Iron	mg/kg	500	489	98	80-120	
Lead	mg/kg	50	47.9	96	80-120	
Magnesium	mg/kg	500	487	97	80-120	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: COAL ASH
Pace Project No.: 92349301

LABORATORY CONTROL SAMPLE: 2057127

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Manganese	mg/kg	50	49.5	99	80-120	
Molybdenum	mg/kg	50	50.4	101	80-120	
Nickel	mg/kg	50	47.6	95	80-120	
Potassium	mg/kg	500	ND	97	80-120	
Selenium	mg/kg	50	48.5	97	80-120	
Silver	mg/kg	25	24.5	98	80-120	
Sodium	mg/kg	500	485J	97	80-120	
Thallium	mg/kg	50	47.4	95	80-120	
Vanadium	mg/kg	50	48.6	97	80-120	
Zinc	mg/kg	50	49.7	99	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2057128 2057129

Parameter	Units	92349212002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/kg	ND	397	403	413	403	104	100	75-125	2	20	
Antimony	mg/kg	ND	39.7	40.3	41.0	41.0	103	102	75-125	0	20	
Arsenic	mg/kg	ND	39.7	40.3	39.6	39.6	100	98	75-125	0	20	
Barium	mg/kg	ND	39.7	40.3	41.2	40.7	104	101	75-125	1	20	
Beryllium	mg/kg	ND	39.7	40.3	41.6	40.9	105	101	75-125	2	20	
Cadmium	mg/kg	ND	39.7	40.3	40.7	40.4	102	100	75-125	1	20	
Calcium	mg/kg	24.8 ug/g	397	403	442	423	105	99	75-125	4	20	
Chromium	mg/kg	ND	39.7	40.3	41.5	40.0	104	99	75-125	4	20	
Cobalt	mg/kg	ND	39.7	40.3	41.1	40.6	104	101	75-125	1	20	
Copper	mg/kg	ND	39.7	40.3	41.8	41.5	105	103	75-125	1	20	
Iron	mg/kg	ND	397	403	415	407	104	100	75-125	2	20	
Lead	mg/kg	ND	39.7	40.3	40.5	39.8	102	98	75-125	2	20	
Magnesium	mg/kg	ND	397	403	414	398	104	99	75-125	4	20	
Manganese	mg/kg	ND	39.7	40.3	41.8	40.6	105	101	75-125	3	20	
Molybdenum	mg/kg	ND	39.7	40.3	42.6	42.3	107	105	75-125	1	20	
Nickel	mg/kg	ND	39.7	40.3	40.3	39.8	102	99	75-125	1	20	
Potassium	mg/kg	ND	397	403	412	ND	102	97	75-125		20	
Selenium	mg/kg	ND	39.7	40.3	40.5	41.0	102	102	75-125	1	20	
Silver	mg/kg	ND	19.8	20.2	20.9	20.5	105	102	75-125	2	20	
Sodium	mg/kg	ND	397	403	413	406	102	99	75-125	2	20	
Thallium	mg/kg	ND	39.7	40.3	40.5	40.7	102	101	75-125	1	20	
Vanadium	mg/kg	ND	39.7	40.3	41.1	40.0	104	99	75-125	3	20	
Zinc	mg/kg	0.881 ug/g	39.7	40.3	42.8	41.0	106	100	75-125	4	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALIFIERS

Project:	COAL ASH
Pace Project No.:	92349301

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to dilution of the sample aliquot.

ND - Not Detected at or above adjusted reporting limit.

TNTC - Too Numerous To Count

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

PQL - Practical Quantitation Limit.

RL - Reporting Limit.

S - Surrogate

1,2-Diphenylhydrazine decomposes to and cannot be separated from Azobenzene using Method 8270. The result for each analyte is a combined concentration.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

Acid preservation may not be appropriate for 2 Chloroethylvinyl ether.

A separate vial preserved to a pH of 4-5 is recommended in SW846 Chapter 4 for the analysis of Acrolein and Acrylonitrile by EPA Method 8260.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

TNI - The NELAC Institute.

LABORATORIES

PASI-A	Pace Analytical Services - Asheville

ANALYTE QUALIFIERS

D3	Sample was diluted due to the presence of high levels of non-target analytes or other matrix interference.

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project:	COAL ASH
Pace Project No.:	92349301

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
92349301001	**FBS 5.79G**	EPA 3050	371289	EPA 6010	371712
92349301002	**NAOHS 10.41G**	EPA 3050	371289	EPA 6010	371712
92349301003	**EB 29.38G**	EPA 3050	371289	EPA 6010	371712
92349301004	**ZVI 34.37G**	EPA 3050	371289	EPA 6010	371712
92349301005	**AMS 3.40G**	EPA 3050	371289	EPA 6010	371712

Laboratory receiving samples:
Asheville ☐ Eden ☐ Greenwood ☐ Huntersville ☑ Raleigh ☐ Mechanicsville ☐

Sample Condition Upon Receipt

Client Name: Redox Tech

Project #:

WO#: 92349301

92349301

Courier: ☐ Commercial ☐ Fed Ex ☑ Pace ☐ UPS ☐ USPS ☐ Other:_____ ☐ Client

Custody Seal Present? ☐ Yes ☑ No **Seals Intact?** ☐ Yes ☑ No

Date/Initials Person Examining Contents: 7-27-17 SR

Packing Material: ☐ Bubble Wrap ☑ Bubble Bags ☐ None ☐ Other:_____

Thermometer:
☐ IR Gun ID: T1603

Type of Ice: ☑ Wet ☐ Blue ☐ None

☑ Samples on ice, cooling process has begun

Correction Factor:

Cooler Temp Corrected (°C): 5.1

Temp should be above freezing to 6°C

Biological Tissue Frozen? ☐ Yes ☑ No ☐ N/A

USDA Regulated Soil (☑ N/A, water sample)

Did samples originate in a quarantine zone within the United States: CA, NY, or SC (check maps)? ☐ Yes ☑ No

Did samples originate from a foreign source (internationally, including Hawaii and Puerto Rico)? ☐ Yes ☑ No

				Comments/Discrepancy:
Chain of Custody Present?	☑ Yes	☐ No	☐ N/A	1.
Samples Arrived within Hold Time?	☑ Yes	☐ No	☐ N/A	2.
Short Hold Time Analysis (<72 hr.)?	☐ Yes	☑ No	☐ N/A	3.
Rush Turn Around Time Requested?	☐ Yes	☑ No	☐ N/A	4.
Sufficient Volume?	☑ Yes	☐ No	☐ N/A	5.
Correct Containers Used?	☑ Yes	☐ No	☐ N/A	6.
-Pace Containers Used?	☑ Yes	☐ No	☐ N/A	
Containers Intact?	☑ Yes	☐ No	☐ N/A	7.
Samples Field Filtered?	☐ Yes	☑ No	☐ N/A	8. Note if sediment is visible in the dissolved container
Sample Labels Match COC?	7-27-17n ~~☑ Yes~~	☑ No	☐ N/A	9. No labels on bottles. Will use 6010s as analysis not analysis on COC.
-Includes Date/Time/ID/Analysis Matrix: SL				
Headspace in VOA Vials (>5-6mm)?	☐ Yes	☐ No	☑ N/A	10.
Trip Blank Present?	☐ Yes	☑ No	☐ N/A	11.
Trip Blank Custody Seals Present?	☐ Yes	☐ No	☑ N/A	

CLIENT NOTIFICATION/RESOLUTION

Field Data Required? ☐ Yes ☐ No

Person Contacted: _____ Date/Time: _____

Comments/Sample Discrepancy: _____

Project Manager SCURF Review: TE **Date:** 7/28

Project Manager SRF Review: TE **Date:** 7/28

Note: Whenever there is a discrepancy affecting North Carolina compliance samples, a copy of this form will be sent to the North Carolina DEHNR Certification Office (i.e. Out of hold, incorrect preservative, out of temp, incorrect containers)

Pace Analytical®	Document Name: Sample Condition Upon Receipt(SCUR)	Document Revised: Sept. 21, 2016 Page 2 of 2
	Document No.: F-CAR-CS-033-Rev.01	Issuing Authority: Pace Quality Office

***Check mark top half of box if pH and/or dechlorination is verified and within the acceptance range for preservation samples.**

****Bottom half of box is to list number of bottles**

Project # WO#:92349301

PM: PTE Due Date: 08/03/17

CLIENT: 92-RedoxTech

Item#	BP4U-125 mL Plastic Unpreserved (N/A) (Cl-)	BP3U-250 mL Plastic Unpreserved (N/A)	BP2U-500 mL Plastic Unpreserved (N/A)	BP1U-1 liter Plastic Unpreserved (N/A)	BP3S-250 mL Plastic H2SO4 (pH < 2) (Cl-)	BP3N-250 mL plastic HNO3 (pH < 2)	BP3Z-250 mL Plastic ZN Acetate & NaOH (>9)	BP3C-250 mL Plastic NaOH (pH > 12) (Cl-)	WGFU-Wide-mouthed Glass jar Unpreserved	AG1U-1 liter Amber Unpreserved (N/A) (Cl-)	AG1H-1 liter Amber HCl (pH < 2)	AG3U-250 mL Amber Unpreserved (N/A) (Cl-)	AG1S-1 liter Amber H2SO4 (pH < 2)	AG3S-250 mL Amber H2SO4 (pH < 2)	AG3A(DG3A)-250 mL Amber NH4Cl (N/A)(Cl-)	DG9H-40 mL VOA HCl (N/A)	VG9T-40 mL VOA Na2S2O3 (N/A)	VG9U-40 mL VOA Unp (N/A)	DG9P-40 mL VOA H3PO4 (N/A)	VOAK (6 vials per kit)-5035 kit (N/A)	V/GK (3 vials per kit)-VPH/Gas kit (N/A)	SP5T-125 mL Sterile Plastic (N/A – lab)	SP2T-250 mL Sterile Plastic (N/A – lab)		BP3A-250 mL Plastic (NH2)2SO4 (9.3-9.7)	Cubitainer	VSGU-20 mL Scintillation vials (N/A)	GN
1									1																			
2									1																			
3									1																			
4									1																			
5									1																			
6																												
7																												
8																												
9																												
10																												
11																												
12																												

pH Adjustment Log for Preserved Samples

Sample ID	Type of Preservative	pH upon receipt	Date preservation adjusted	Time preservation adjusted	Amount of Preservative added	Lot #

Pace Analytical

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page : 1 **Of** 1

Section A
Required Client Information:

Company: Redox Tech, LLC
Address: 200 Quade Dr
Cary, NC 27513
Email: rossabi@redox-tech.com
Phone: 919-678-0140 Fax 919-678-0150
Requested Due Date: 5 day

Section B
Required Project Information:

Report To: Joe Rossabi
Copy To:
Purchase Order #:
Project Name: Coal Ash
Project #:

Section C
Invoice Information:

Attention:
Company Name:
Address:
Pace Quote:
Pace Project Manager: taylor.ezell@pacelabs.com,
Pace Profile #: 8670-1

Regulatory Agency

State / Location
NC

MATRIX	CODE
Drinking Water	DW
Water	WT
Waste Water	WW
Product	P
Soil/Solid	SL
Oil	OL
Wipe	WP
Air	AR
Other	OT
Tissue	TS

ITEM #	SAMPLE ID One Character per box. (A-Z, 0-9 / , -) Sample Ids must be unique	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED START DATE	COLLECTED START TIME	COLLECTED END DATE	COLLECTED END TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS
1	FBS 5.79g	SL		7/26/17	9:47				1
2	NaOHS 10.41g	SL		7/26/17	10:32				1
3	EBS 29.38g	SL		7/25/17	10:34				1
4	ZVIS 34.37g	SL		7/25/17	9:58				1
5	AMS 3.40g	SL		7/25/17	10:17				1
6									
7									
8									
9									
10									
11									
12									

ITEM #	Preservatives: Unpreserved	H2SO4	HNO3	HCl	NaOH	Na2S2O3	Methanol	Other
1	1							
2	1							
3	1							
4	1							
5	1							
6								
7								
8								
9								
10								
11								
12								

Requested Analysis Filtered (Y/N)

ITEM #	Analyses Test Y/N	Alkalinity, TDS, TS	Chloride, Fluoride	Ignitability	Total Phosphorus	Sulfide	Total Metals							Residual Chlorine (Y/N)	92349301
1		✓	✓	✓	✓	✓	✓								001
2		✓	✓	✓	✓	✓	✓								002
3		✓	✓	✓	✓	✓	✓								003
4		✓	✓	✓	✓	✓	✓								004
5		✓	✓	✓	✓	✓	✓								005
6															
7															
8															
9															
10															
11															
12															

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	TEMP in C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)
		7/26/17	1415	Pace	7/26/17	1415	AmB	N	N	Y
	Pace 7/27/17	~~7/27/17~~	0750		7/27/17	0750				
		7/27/17	1242	Pace HU	7-27-17	1242	5.1	Y	N	Y

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: ROSSABI
SIGNATURE of SAMPLER:
DATE Signed: 7/26/17

Appendix B
Sampling and Analysis Plan

COAL COMBUSTION PRODUCT DISPOSAL PROGRAM

GALLATIN FOSSIL PLANT
Sumner County, Tennessee

Sampling and Analysis Plan

Treatability Study
Non-Registered Site (NRS)

Prepared for

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402-2801

September 27, 2019

Prepared by

AECOM

1600 Perimeter Park Drive, Suite 400
Morrisville, North Carolina 27560
Tel: 919.461.1100
Fax: 919.461.1415

TABLE OF CONTENTS

APPENDICES

1.0 Background

On behalf of the Tennessee Valley Authority (TVA), AECOM has prepared the following Sampling and Analysis Plan (SAP) to accompany the Non-Registered Site (NRS) Treatability Test Work Plan (NRS Work Plan). The NRS Work Plan was developed in response to the Tennessee Department of Environment and Conservation (TDEC) Commissioner's Order Number OGC19-0004 (the Order), which requires that TVA conduct a laboratory treatability test and field demonstration aimed at adjusting pH to sequester metals along the Non-Registered Site (NRS) boundary adjacent to the Cumberland River at TVA's Gallatin Fossil Plant (GAF).

The majority of field activities in the NRS Work Plan are relatively common activities, such as drilling, water sampling, soil sampling, etc. The SAPs developed under the GAF Environmental Investigation Plan (EIP; AECOM 2016a) and previously approved by TDEC will be used for these activities, as referenced in the NRS Work Plan. This SAP presents procedures for implementation of field activities identified in the NRS Work Plan that are not included in the previous EIP SAPs. This SAP will also include a Quality Assurance (QA) Addendum to address QA elements not specifically addressed in the existing Quality Assurance Framework (QAF) (TVA, 2017) or QA addenda provided in SAPs developed under the GAF EIP.

2.0 Objectives

This SAP will support implementation of the NRS Work Plan, which was developed to obtain treatability data and determine whether pH and geochemical conditions can be adjusted in groundwater at the NRS, and if such an adjustment can be an effective method to meet the groundwater protection standards (GWPS) at the NRS boundary compliance points. Specific objectives for the field work include the following:

- To update the conceptual site model (CSM) with additional information regarding location of the low-pH source material, the primary groundwater transport pathways and velocities between the source area and the downgradient boundary, solute flux in field demonstration areas, and the feasibility of various remedial amendment delivery mechanisms;
- To obtain material for the bench-scale treatability studies; and
- To develop preliminary design data for the pilot field demonstration.

3.0 Project Team and Responsibilities

The following people comprise the core of the AECOM project team:

- David Skeggs, P.E. will lead the project team as Project Manager for the activities detailed in this SAP. He will also serve as TVA's point of contact and source of regular updates and project scheduling and accounting components.
- Gabe Lang, P.E. will continue to support the project team as Program Manager for this project.
- Patrick Haskell will serve as the technical project team leader coordinating the investigation, treatability testing, and reporting activities.
- Craig MacPhee will serve as the senior remediation engineer, directing the treatability testing activities, interpreting test results, and adapting the treatability testing process to maximize the utility of the data obtained.
- Mary Stauffer will provide hydrogeologic expertise for evaluating the results of the investigation with respect to site geology and groundwater flow.
- Richard Henry, Ph.D. will provide geochemistry expertise for evaluating/interpreting the chemical and geochemical data generated from treatability testing activities and groundwater sampling events.
- Francisco Barajas-Rodriquez is the laboratory director for the treatability testing and will manage laboratory personnel and directly oversee the performance of laboratory treatability tests and data collection.

Environmental Standards, Inc. will provide quality assurance and data management services for the analytical data collected as part of the project.

The following people comprise the TVA project team leadership. Contact information is provided for inquiries from non-project personnel:

- Michael Clemmons will address individual inquiries. Michael can be reached at (423) 751-4029.
- Jason Curtsinger will manage the technical aspects of the project for TVA.

4.0 Health and Safety

An AECOM site safety officer (SSO) will be on-site during implementation of the NRS Work Plan. Prior to starting field activities, the SSO will review site conditions and site objectives to identify potential hazards, particularly those that may increase the risk of an incident affecting people, property, or the environment. Potential risks and associated risk abatement measures will be reviewed in the context of a site-specific health and safety plan (HASP) and will be discussed during the daily pre-job and post-job briefs. Each task will be defined along with task-specific hazard analyses. A 2-minute rule-card will be filled out at each unique work location, or when site conditions change. The site-specific AECOM HASP will be reviewed for completeness and updated to address new activities prior to initiating field work.

Site-specific safety requirements for on-site personnel are anticipated to include OSHA10 training, background check, drug testing, and completion (annually) of site-specific (GAF) safety training. AECOM employees and subcontractors performing work activities onsite will be required to meet the above requirements.

5.0 Field Investigation

The field investigation will consist of groundwater sampling from monitoring wells and soil borings and collection of soil samples from soil borings. Samples will be collected for field and laboratory analysis as well as bench scale treatability testing. Field investigation activities will also include hydraulic conductivity testing and installation of monitoring wells. Details of the laboratory treatability testing are provided in the NRS Work Plan.

5.1 Data Quality Objectives

The samples and analyses being performed in association with this work are primarily being used to aid in the selection of remedial amendments that will be subjected to further testing to evaluate their utility for application in the field demonstration and possibly full-scale groundwater remediation. As such, data quality objectives (DQOs) for the treatability test will differ from those of the ongoing Environmental Investigation of the site. Because certain data (e.g., metals concentrations in appropriately-constructed monitoring wells) may eventually be used for assessment of the nature and extent of COCs, the DQOs and QA procedures associated with such analyses will be unchanged from those identified in the Environmental Investigation Plan (EIP; AECOM 2016a). However, much of the data to be obtained from the investigation are analogous to field screening data and will be employed to guide the next steps of the field work or as part of a weight of-evidence evaluation to guide the treatability testing and will not be used for direct assessment of exposures. Therefore, DQOs and associated QA protocols will sometimes differ markedly from those described for the EIP. The sampling procedures and analyses to be performed as part of the treatability testing program are described below, and details of QA procedures associated with analyses unique to the treatability test are described in Appendix A.

5.2 Execution

The field work described herein will be executed under the oversight of experienced scientists and engineers and office support staff. The primary points of contact for field teams will be the Field Team Leader. A team of office support staff will be in regular communication with the field team to support safety, quality, and efficiency of field efforts.

All site workers will be responsible for following the health and safety procedures established in the AECOM site-specific HASP and Work Package. Daily health and safety briefings/tailgate meetings will be conducted to review job-related activities and address potential hazards associated with these activities. Job Safety Analyses (JSAs) will be prepared and presented in the TVA Work Package for each task prior to performing work, and updated in the field to reflect any change in conditions affecting the tasks being performed. TVA-specific protocols will be followed, including the completion of 2-minute rule cards at each work site. All personnel conducting groundwater sampling activities will be qualified in proper groundwater sampling and safety procedures.

Electronic recordkeeping will frequently be used to enhance the efficiency of field data collection efforts. Field notes, whether electronic or written, will be uploaded promptly to the project server. Details regarding record keeping were provided in TVA's Technical Instruction (TI) for Field Record Keeping, which is provided Appendix B.

5.3 Groundwater Sampling

Monitoring well sampling will be performed via low-flow methods, as described in the GAF Groundwater Sampling SAP (AECOM 2016c) and in accordance with TVA's TI for Groundwater Sampling (ENV-TI-05.80.42), Field Measurement Using a Multi Parameter Sonde TI (ENV-TI-05.80.46) and Field Sampling Quality Control (ENV-TI-05.80.04), which are provided in Appendix B. The NRS Work Plan provides the details regarding the wells to be sampled and analytes for this investigation. Note that analytes used to characterize redox conditions or conditions specific to the treatability test may have a reduced set of quality control (QC) samples, as described in the QA Addendum provided as Appendix A.

The QA Addendum also addresses analytes not included in approved EIP SAPs or the QAF. Groundwater samples collected for the treatability study may be filtered in the field, depending upon the nature of the sampling and data quality objectives, as described in the sections below. For the initial sampling from monitoring wells, both filtered and unfiltered groundwater samples will be submitted for laboratory analysis of metals to develop the conceptual site model. For the sampling from soil borings, groundwater samples will be filtered to limit the presence of drill cuttings in the samples. Groundwater collected in bulk for use in the treatability tests will not be filtered in the field, and the QC sample requirements identified in ENV-TI-05.80.04 will not be directly followed as that water is not designated for conventional laboratory analysis.

5.3.1 Groundwater Profiling

Groundwater profiling will be conducted at selected locations and depths using hydraulic profiling tool (HPT) and DPT methods. The groundwater profiling locations are located in the vicinity of well GAF-444U and are depicted on Figure 3-1 of the NRS Work Plan. Groundwater samples may also be collected from potential source area soil borings, if a sufficiently transmissive zone is encountered during drilling. Figure 3-1 also depicts locations of potential source area soil borings.

Hydraulic Profiling Tool

HPT is a Geoprobe-based direct push tool that is advanced into unconsolidated sediments to assess formation permeability and hydrostratigraphy at the centimeter scale. The HPT is capable of logging injection pressure, flow rate, and electrical conductivity, and conducting pressure dissipation tests to measure hydrostatic pressure to characterize the piezometric profile and estimate water table elevation. The tooling will be attached to the DPT equipment in accordance with manufacturer’s specifications (see attached SOP) by a qualified subcontractor. The HPT probe will be installed at the end of the drilling rods and advanced via pushing or hammering at a rate of approximately 2 centimeters per second (cm/sec). As the probe is advanced, clean water is pumped through a screen on the side at a rate of less than 300 milliliters per minute. Data is collected in real time by the field controller instrument. Pressure dissipation testing is conducted when the probe is held at a static depth. The data will be used to identify permeable zones within the subsurface.

Downhole equipment will be decontaminated in accordance with TI for Field Sampling Equipment Cleaning and Decontamination (ENV-TI-05.80.05), which is included in Appendix B.

Groundwater Sampling with DPT tooling

Based on the results of the HPT investigation, DPT will be used to collect groundwater samples for field and/or laboratory analysis. Borings for groundwater sampling will be drilled at locations adjacent to HPT locations where more permeable sand lenses were identified in the HPT logs. Sampling depths will be selected to intersect the more permeable intervals, as the clay soils that comprise the bulk of the alluvium are not expected to transmit sufficient groundwater to allow sampling with DPT tooling.

The borings will be advanced using a DPT drill rig equipped with 4 or 5-foot long, 2.25- or 3.25-inch outside diameter drilling rods. The lowest probe rod will be equipped with a drive point connected to a screen point that is typically one to two feet long. When the target depth is reached, the screen will be exposed to allow groundwater to flow into the screened interval. Groundwater samples will then be collected using new, clean polypropylene tubing connected to an inertial check valve or a peristaltic pump. Samples will be collected for field measurement pH and turbidity, using stand-alone meters, and if sufficient yield is obtained to allow readings to stabilize in a flow through cell, dissolved oxygen (DO) and ORP. Groundwater samples will be placed in the decontaminated protective cup associated with the multiparameter sonde (such as the YSI-556 Multiprobe System), and the sonde will be placed in the water sufficiently long for the readings to stabilize in accordance with TVA TI for Field Measurement using a Multiparameter Sonde (ENV-TI-05.80.46) . If sufficient water is present, the water will instead be passed through a low-flow cell to measure these parameters consistent with the low flow sampling protocols described in the Groundwater Sampling SAP (AECOM 2016c).

Where low pH is observed (< 5 standard units [S.U.]) and sufficient groundwater yield is obtained, a groundwater sample will be collected for laboratory analysis of dissolved beryllium, cadmium, lithium, nickel, and iron by field-filtering to remove suspended particles using the procedures presented in Section 3.6 Filtration of Groundwater Samples in ENV-TI-05.80.42. If sufficient yield is obtained, a second groundwater sample may also be collected for laboratory analysis of total beryllium, cadmium, lithium, nickel, and iron.

Once sample collection is complete at a given depth and boring, the probe rods will be advanced to the next sampling depth. If the same borehole is utilized for multiple sampling depth, the lower sampling depth will have at least 10 feet of vertical separation from the prior sampling depth. Downhole equipment will be decontaminated between drilling locations in accordance with TI for Field Sampling Equipment Cleaning and Decontamination (ENV-TI-05.80.05), which is provided in Appendix B.

5.3.1 pH Measurement

PH will typically be measured in groundwater purged from wells in accordance with the procedures described in the Groundwater Sampling SAP (AECOM 2016c). In certain cases (e.g., for screening of saturated soil or where insufficient water can be produced to read with a pH meter), a sample may be placed directly onto a piece of pH paper (i.e., Hach® pH Paper, 0-14 pH Range or equivalent) to rapidly assess pH. Manufacturer instructions will be followed for reading the pH.

Field-measured aerated pH values will be collected from monitoring wells and, if sufficient water volume is available, from groundwater profiling locations, using a calibrated multiparameter sonde or a pH/temperature sonde. Approximately 100 mL of water, or sufficient water to submerge the electrodes of the pH sonde, will be pumped from the sampling location into a decontaminated beaker or other glassware. After measuring the initial pH, the water will be stirred for 15 seconds vigorously with a clean glass stirring rod. The pH will then be measured again. Before recording pH measurements, either before or after stirring, the sonde will be submerged for at least 30 seconds.

5.3.2 Field test kits

Several parameters that are integral to understanding the geochemistry that the treatability testing must address can be subject to increasing error with increasing time that passes between sample collection and analysis. Such analyses are those which can be affected by atmospheric interactions that may change the concentration of an analyte directly or may result in changes in an analyte concentration due to changing redox conditions. Where such considerations are the primary potential source of error, field test kits will be employed to manage that potential for error.

Groundwater samples from monitoring wells and/or groundwater profiling borings will be field-analyzed for ferrous iron using the Hach ® Ferrous Iron Color Disk Test Kit, model IR-18C, 0.2-7 mg/L. Water samples collected from soil borings will be filtered prior to using the iron field test kits. Ferric iron concentrations will be estimated by subtracting the ferrous iron concentration from the total iron concentration obtained by laboratory analysis.

Groundwater samples from monitoring wells or groundwater profiling borings will be analyzed in the field for sulfide using a field test kit employing EPA Test Method 8131 (Hach® Sulfide Reagent Kit, Methylene Blue or equivalent).

Dissolved carbon dioxide concentrations will be measured using the Hach ® Carbon Dioxide Test Kit, Model CA-23 or equivalent. Detailed instructions for the Hach® kits are included in Appendix B. Water samples will not be filtered prior to using the carbon dioxide field test kit.

5.3.3 Treatability Study

Groundwater for the treatability test will be collected from monitoring wells using low-flow methods, as described in the GAF Groundwater Sampling SAP (AECOM 2016c) and in accordance with TVA's TI for Groundwater Sampling (ENV-TI-05.80.42), Field Measurement Using a Multi Parameter Sonde (ENV-TI-05.80.46) and Field Sampling Quality Control (ENV-TI-05.80.04), which are provided in Appendix B. Purge rates will be the maximum rate (up to 500 milliliters per minute per ENV-TI-05.80.42) at which drawdown and field measurement parameters remain stabilized without increasing turbidity beyond levels typically associated with a given well. Water collected for the treatability study will be pumped from monitoring wells, placed in four-gallon collapsible plastic coainers that are sealed and taped shut prior to shipment on ice to the treatability study laboratory. Previous treatability testing data (see Appendix A of the NRS Work Plan) indicate that significant changes to redox conditions and metals concentrations did not occur using this sample collection and storage method. This may be due to the acidity of the groundwater in the area, which may be considered analogous to established sample preservation methods for total metals analysis.

During the course of the treatability study, the treatability laboratory will collect samples for laboratory analysis. Samples will be collected directly from testing apparatuses at flow rates that minimally aerate samples to preserve and allow collection of samples with turbidity measurements generally consistent with that of groundwater samples collected in the field. Filtration of post-treatment treatability test samples will be performed on an as-needed basis to assess fractions of analytes in dissolved and suspended forms.

Some analyses identified in the NRS Work Plan may be conducted by the treatability laboratory (e.g., sulfide, ferric iron) for purposes of observing the progress of treatability tests. These data will not be used for decisions regarding risk or compliance, but are rather to guide the course of the treatability test and are screening methods, that will generally follow the procedures for measurement of such parameters in the field. Treatability test samples will be analyzed for metals at the same labs as groundwater samples.

5.4 Soil Sampling

Advancement of soils borings via DPT, hollow-stem auger, or sonic drilling and general procedures for collection of soil into laboratory-provided containers and Shelby tubes are included in the Overburden Soil Borings SAP (AECOM 2016d). Soil samples will be collected every five feet of soil boring and when the geologic materials change for analysis of pH, by mixing soil with deionized (DI) water, as described in Section 5.4.1.

Soil samples will be collected for acid base accounting (ABA) based on the results of soil pH measurement and visual observations of soil materials. Samples will primarily be selected from among intervals that display low pH (i.e., < 5 S.U.) and/or visual evidence of pyrite/iron. The ABA parameters include total sulfur, sulfate, pyritic sulfur, residual sulfur, acid neutralization potential and net acid neutralization potential. Additional information on the analysis of these parameters is included in Appendix A.

Samples collected for treatability testing will be composited from intervals of interest (e.g., intervals with pyrite source material, intervals known to have low pH based on soil sampling, existing monitoring well screen intervals, etc.). The thickness of intervals for composite sample collection may range from one to ten feet. In some areas, sample volume requirements may require the advancement of adjacent borings to obtain sufficient sample volume from the desired interval. Samples for treatability testing will be collected in one to five-gallon plastic buckets and will be composited in the laboratory.

5.4.1 Soil pH

Soil pH will be measured using the following procedure:

- Use a sieve, if necessary, to ensure tested soil is ¼ in (6.3 mm) or smaller.
- Weigh and place 30 grams of soil into a glass beaker using a calibrated balance or calibration-checked scale.
- Add 30 milliliters of distilled water to the soil sample. Use a glass rod to stir to obtain a slurry, the cover with a watch glass.
- Allow the sample to stand for a minimum of one hour, stirring every 10 to 15 minutes.
- Stir the slurry sample well just before placing a calibrated pH meter into the mixture, ensuring good contact between the electrode and the water without placing the pH electrode into the soil. Tilt the beaker if necessary, and keep the electrode immersed for at least 30 seconds to allow the meter to stabilize. Record the pH value to the nearest 0.1 S.U.

Once pH measurements are complete, the beaker and pH probe should be rinsed thoroughly with DI water.

5.4.2 Treatability Study

During the course of the treatability study, the treatability laboratory may collect samples for laboratory analysis from select post-treatment soil columns or microcosms. These samples will be collected to assess the minerology of sequestered metals removed during treatability testing. Potential analyses not included in previous SAPs or the QAF include sequential extraction and x-ray diffraction (XRD). The sequential extraction process that may be used during the treatability test is a non-standard methodology developed by Eurofins Test America and is described in Appendix A. Additional information on the laboratory protocols, sample bottles, and appropriate preservatives for these procedures are included in Appendix A.

5.5 Hydraulic Conductivity Testing

Protocols for hydraulic conductivity testing using slug tests is included in the Hydrogeologic Characterization SAP (AECOM 2016b). Where testing indicates lower permeability, drawdown monitoring data from low-flow groundwater sampling may be used to provide an independent check of hydraulic conductivity testing results. If applicable, data from low-flow sampling will be analyzed using the method of Robbins et al. (2008).

5.6 Monitoring Well Installation

The protocol for installation of monitoring wells via hollow stem auger, air rotary, or sonic drilling methods are described in the Well Installation SAP (AECOM 2016e) and TVA's TI for Monitoring Well Installation and Development, ENV-TI-05.80.25, which is included in Appendix B.

As described in the NRS Work Plan, locations and screened intervals will be selected based on the results of soil and groundwater investigations.

5.7 Equipment Decontamination

All non-dedicated sampling equipment will be cleaned in accordance with TVA's TI for Field Sampling Equipment Cleaning and Decontamination (ENV-TI-05.80.05), which is provided in Appendix B. Decontamination of water level meters and water quality meters will be performed upon arriving to a new sampling location. Equipment will be placed in a trash bag or other separate container during transport to prevent cross-contamination. Decontamination activities will be documented in the field book, field data sheet, or Daily Record of Events.

5.8 Waste Management

Investigation derived waste (IDW) will be managed in accordance with applicable TIs. Soil and water IDW generated during drilling, well installation and development, and equipment decontamination will be managed in accordance with ENV-TI-05.80.25, Section 6.20 (Appendix B). Water IDW generated during groundwater sampling will be managed in accordance with ENV-TI-05.80.42, Section 6.9 (Appendix B).

5.9 Sample Custody

Soil and groundwater samples will be managed in accordance with TVA's TI for Sample Labeling and Custody (ENV-TI-05.80.02), which is provided Appendix B. If any deviations from these protocols occur, the samples are considered to have failed to maintain sample custody and data usability will be assessed in consideration of the DQOs of the intended analyses.

5.10 Sample Analysis

Except for in-house sampling conducted by the treatability study laboratory to guide the course of treatability testing and specialized analyses (e.g., XRD and ABA), samples will be submitted to Eurofins Test America for analysis. Sample containers and preservation requirements for compounds not included in the QAF or existing SAPs are presented in the QA Addendum to this SAP (Appendix A).

5.11 Documentation

Record-keeping will be performed in accordance with TVA TI for Field Record Keeping (ENV-TI-05.80.03), which is provided Appendix B. Field notes will be uploaded promptly (generally on a daily basis) onto the project server.

5.12 Quality Assurance and Data Management

5.12.1 Quality Assurance/Quality Control

A comprehensive quality assurance (QA) program has been developed for the site and will govern quality aspects of all work performed under the EIP. The QA program covers collection, analysis, reporting, and use of data associated with the EI, as applicable. Details of the program are presented in the TVA GAF QAF (ESI 2017) which provides QA procedures and quality control (QC) measures to be applied to associated investigative and monitoring activities. QA/QC procedures applicable to investigative activities presented in this SAP include:

- Field Documentation
- Record Keeping
- Equipment Testing/Inspection, Calibration, and Maintenance
- Assessments and Response Actions
- Reporting
- Reconciliation of Data to Project Objectives

Specific QA requirements for treatability test-specific activities are presented in the QA Addendum provided in Appendix A.

Field Documentation

Field data collected during the EI will be evaluated for usability by conducting a QA review, which will consist of checking the procedures used by field staff and comparing the boring logs and data to historical data. The field data will be reviewed by the Field Lead and/or QA Oversight Manager or designee for the following:

- Content of daily field notes
- Completeness of field forms
- Field equipment calibration method, frequency, and documentation
- Procedural compliance with the EIP and applicable support documents (e.g, SAP, QAF)

Any deviations from applicable work plans will be documented in the field logbook during sampling and data collection operations. The TVA Project Manager and QA Oversight Manager or designee will be notified of deviations.

Record Keeping

Appropriate records will be maintained in a secure AECOM project file to provide adequate documentation of the entire treatability testing process prior to transfer to the TVA project file. The TVA project file will be the central repository for documents relevant to investigation activities as described in this SAP. Electronic and hardcopy data will be archived for a minimum of 10 years from the date of report. TVA will maintain a complete project file and will archive hardcopy and electronic data in accordance with TVA records retention rules.

Equipment Testing/Inspection, Calibration, and Maintenance

Field equipment will be inspected and tested prior to initiation of fieldwork by the field team members and if necessary, repairs will be made prior to equipment use. Field equipment will be properly inspected, charged, and in good working condition prior to the beginning of each working day. If equipment is not in the proper working condition, that piece of equipment will be repaired or taken out of service and replaced with a redundant backup prior to use. At the end of each working day, field equipment and instruments will be properly decontaminated, taken out of the field, and appropriately placed for overnight storage and/or charging. Equipment, instruments, tools, and other items requiring preventive maintenance will be serviced in accordance with the manufacturer’s recommendations and written procedures specified in the manufacturer’s instructions.

For instruments requiring field calibration, calibrations will be conducted in accordance with the manufacturer’s specifications and at the frequency recommended by the manufacturer and as specified in the TVA TI for Field Measurement using a Multiparameter Sonde (ENV-TI-05.80.46), which is provided in Appendix B. Personnel performing instrument calibrations/standardizations shall be trained in its proper operation and calibration. Records of instrument calibration/standardization will be maintained in the project files and will be subject to audit by the QA Oversight Manager or designee.

The calibration records will include documentation of the following information:

- Instrument name and serial number
- Name of person performing the calibration
- Date of calibration
- Calibration standards, including lot numbers and expiration dates
- Results of the calibration

Field instruments that do not meet the calibration requirements will be recalibrated or taken out-of-service until acceptable performance can be verified.

Assessments and Response Actions

Field personnel have the initial responsibility to monitor the quality of field measurements and observations. Field data will be reviewed for reasonableness and completeness. In addition, random checks of sampling and field conditions will be made to confirm the recorded observations. The Field Team Leader is responsible for verifying that QC procedures are followed. This responsibility requires the Field Team Leader to assess the correctness of field methods and the ability to meet QA objectives. Whenever possible, peer review will also be incorporated into the QA review process in order to maximize consistency among field personnel. If a problem occurs that might jeopardize the integrity of the project or may cause a specific QA objective not to be met, the Field Team Leader will notify the TVA Technical Manager and QA Oversight Manager. An appropriate corrective action will then be determined and implemented. The Field Team Leader will document the problem, the corrective action, and the results. A copy of the corrective action documentation form(s) will be provided to the TVA Technical Manager and the QA Oversight Manager.

Field audits will be conducted by the QA Oversight Manager to ensure the performance of field teams and assess how team performance may affect data quality. As part of this effort at least one field audit will be conducted. Additional field audits will be conducted at the discretion of the TVCA Technical Manager in discussions with the QA Oversight Manager.

Reporting

The Field Team Leader will provide the TVA Technical Manager with routine field progress reports. The TVA Technical Manager (or designee) and QA Oversight Manager will be immediately notified about field situations that require corrective action. Documentation of systems and performance audits and any resulting corrective actions will be maintained as part of the Project File. Audit documentation will be reported to the TVA Technical Manager.

Reconciliation of Data to Project Objectives

The QA Oversight Manager, in conjunction with the TVA Technical Manager, will determine whether field data meet the requirements necessary for decision-making. The field investigation results will be compared to the DQO requirements established during development of the NSR Work Plan and this SAP.

5.12.2 Data Management

The TVA GAF environmental investigation data management process includes:

- Data Collection
- Data Check and Verification

- Data Processing
- Data Storage

Data collection will be standardized and organized for the project team's use. A standardized file nomenclature will be determined and utilized for the duration of the project. Information input on iPads such as daily field notes, boring logs and other field forms, permeability test data, water level measurements and water quality parameters will be uploaded to a drop box on a daily basis to prevent accidental loss of data in the field. QA procedures will be implemented for each field document and data transfer step to assure that a complete, correct Project File is maintained.

Additionally, during implementation of the field event, AECOM will maintain copies of project files on-site for the duration of the project to aid in conducting a successful field effort; to include project plans (NRS Work Plan, this SAP, and the current HASP), maps and drawings, field forms, technical reports, correspondence, and other pertinent information.

5.13 Reporting and Deliverables

A treatability test report will be prepared and submitted to TDEC at completion of the laboratory-based treatability study. The treatability test data will be compiled, evaluated, and the results discussed in the context of application of the remedial amendments at the NRS. The report will assess treatability test execution with respect to the objectives and performance standards identified. The treatability report will discuss chemical design parameters (e.g., one or more remedial amendments, dosing rates) for the field demonstration. However, details of the field demonstration will be provided in a separate field demonstration work plan.

6.0 References

AECOM. 2016a. Environmental Investigation Plan, Rev. 1. TVA Gallatin Fossil Plant. June 20, 2016.

AECOM. 2016b. Sampling and Analysis Plan, Hydrogeologic Characterization, Environmental Investigation Plan, Revision 2. August 23, 2016.

AECOM. 2016c. Sampling and Analysis Plan, Groundwater Sampling, Environmental Investigation Plan, Revision 1. October 14, 2016.

AECOM. 2016d. Sampling and Analysis Plan, Overburden Soil Borings, Native Soil Characterization and Seep Sampling, Environmental Investigation Plan, Revision 1. October 14, 2016.

AECOM. 2016e. Sampling and Analysis Plan, Well Installation, Environmental Investigation Plan, Revision 1. November 8, 2016.

ESI. 2017. Tennessee Valley Authority, Gallatin Fossil Plant Environmental Investigation Quality Assurance Framework, Revision 1, April 2017.

Robbins, G., A.T. Aragon-Jose, A. Romero. 2008. Determining hydraulic conductivity using pumping data from low-flow sampling. Ground Water 47(2):271-86.

APPENDIX A
QUALITY ASSURANCE ADDENDUM

APPENDIX A: QUALITY ASSURANCE FRAMEWORK ADDENDUM

A.1 Introduction

The Tennessee Valley Authority (TVA) Gallatin Fossil Plant (GAF)-Quality Assurance Framework (QAF) was developed to provide a framework for the quality assurance (QA) program associated with the ongoing Environmental Investigation (EI) at GAF. The purpose of this QA Addendum to the Non-Registered Site (NRS) Treatability Study Sampling and Analysis Plan (SAP) is to describe QA aspects of the Treatability Study sampling not addressed in the TVA-GAF-QAF. A crosswalk table is included in Table A-1 that references requirements from the TVA-GAF-QAF to the specific sections of the SAP or the NRS Treatability Test Work Plan (Work Plan; September 2019) in which these requirements are addressed. Elements of the TVA-GAF-QAF not addressed in the SAP or Work Plan are detailed in the QA Addendum sections below.

Table A-1: SAP and Work Plan QA Elements Crosswalk Table

Required Element	TVA-GAF-QAF Section	SAP Section	Work Plan Section
Sampling Schedule	5.2	12.0	7.0
Detailed description of sampling activities	9.0	5.0	3.2
Investigative rationale	9.0	2.0	3.1
Description of sampling design and execution of monitoring activities	9.0	5.0	NA
Site maps including sampling locations	9.0	NA	Figure 3-1
Sample identification procedures	9.0	5.8, ENV-TI-05.80.02	NA
Sampling procedures	10.0	5.3, ENV-TI-05.80.42; ENV-TI-05-80.46; ENV-TI-05-80.04	NA
Sample packing and handling procedures	10.0	ENV-TI-05.80.06	NA
Decontamination procedures	10.2	5.7, ENV-TI-05.80.05	NA
Description of COC and label generation process	11.0	ENV-TI-05.80.02	NA
Sample Custody	11.0	ENV-TI-05.80.02	NA
Field documentation procedures	11.1	5.10, ENV-TI-05.80.03	NA

Required Element	TVA-GAF-QAF Section	SAP Section	Work Plan Section
Sample nomenclature	11.1	5.8, ENV-TI-05.80.02	NA
Description of field monitoring activities	NA	NA	NA
Description of field analytical equipment	12.1 and 14.1	5.3.1, 5.3.2, 5.4.1, and 5.5	NA

A.2 Sample Chemical Analysis

The analyses required under the Treatability Study SAP will be conducted by the laboratory(ies) identified in Table A-2.

Table A-2: Analytical Laboratory Contact Information

Matrix	Parameter	Laboratory	Facility Address	Laboratory Contact
Groundwater	Metals, General Chemistry Parameters	Eurofins TestAmerica	301 Alpha Dr, Pittsburgh, PA 15238	Gail Lage (gail.lage@testamericain.com)
	Radiological Parameters	Eurofins TestAmerica	13715 Rider Trail N, Earth City, MO 63045	
	Treatability Testing	AECOM	9400 Amberglen Blvd Building D Austin, TX, 78729	Franciso Barajas Rodriguez (francisco.barajas@aecom.com)
Soil	Treatability Testing	AECOM	9400 Amberglen Blvd Building D Austin, TX, 78729	Franciso Barajas Rodriguez (francisco.barajas@aecom.com)
	Acid-Base Accounting	ALS Environmental (or equivalent)	3860 S. Palo Verde Rd Suite 302 Tucson, AZ 85714	TBD
	X-Ray Diffraction	DCM Science (or equivalent)	12421 W. 49th Avenue Unit #6 Wheat Ridge, CO 80033	TBD
	Sequential Extraction Procedure	Eurofins TestAmerica	5815 Middlebrook Pike Knoxville, TN 37921	Gail Lage (gail.lage@testamericain.com)

Table A-3 provides requirements for sample containers, recommended mass/volume, sample preservation, and analytical holding time.

Table A-3: Sample Containers, Volume, Preservation, and Holding Time Requirements

Matrix	Parameter	Container Type	Recommended Sample Volume	Preservation	Holding Time
Groundwater	Total Metals	250-mL HDPE	250 mL	HNO_3 to pH < 2 Cool to <6°C	180 days
	Total Mercury				28 days
	Dissolved Metals	250-mL HDPE	250 mL	HNO_3 to pH < 2 Cool to <6°C	180 days
	Dissolved Mercury				28 days
	Anions (Chloride, Fluoride, and Sulfate)	250-mL HDPE	250 mL	Cool to <6°C	28 days
	Total Dissolved Solids (TDS)	250-mL HDPE	100 mL	Cool to <6°C	7 days
	Total Suspended Solids (TSS)	1-L HDPE	1000 mL	Cool to < 6°C	7 days
	Radiological Parameters	3 x 1-L HDPE	3000 mL	HNO_3 to pH < 2	180 days
	Total Kjeldahl Nitrogen	1-L HDPE	1000 mL	Cool to <6°C	7 days
	Alkalinity (Total, Carbonate, Bicarbonate, and Hydroxide)	250-mL	250-mL	Cool to <6°C	28 days
	Total Organic Carbon	2x 40-mL VOA Vial	40-mL	H_2SO_4 to pH < 2	28 days
	Nitrate-nitrite nitrogen	250-mL HDPE	250-mL	H_2SO_4 to pH < 2	28 days
	Treatability Testing	4-gal collapsible plastic (or similar)	TBD*	Cool to <6°C, minimize headspace	30 days
Soil	Treatability Testing	5-gal bucket (or similar), Shelby tubes	TBD*	Cool to <6°C, minimize headspace	Test Duration
	pH (field measurement)	4-oz G	30 g	NA	ASAP
	Metals	4-oz G	5 g	Cool to < 6°C	180 days

Matrix	Parameter	Container Type	Recommended Sample Volume	Preservation	Holding Time
Soil	Mercury	4-oz G	5 g	Cool to < 6°C	28 days
	Total Inorganic Carbon	8-oz G	20 g	Cool to <6°C	28 days
	Total Organic Carbon				
	Sequential Extraction Procedure	16-oz G	100 g	Cool to < 6°C	NA
	X-Ray Diffraction	4-oz G	5 g	none	NA
	Acid-Base Accounting	4-oz G	5 g	Cool to < 6°C	28 days
Aqueous Equipment Blanks**	Total Metals	250-mL HDPE	250 mL	HNO_3 to pH < 2 Cool to < 6°C	180 days
	Total Mercury				28 days
	Dissolved Metals	250-mL HDPE	250 mL	HNO_3 to pH < 2 after filtration Cool to < 6°C	180 days
	Dissolved Mercury				28 days
	Anions (Chloride, Fluoride, and Sulfate)	250-mL HDPE	250 mL	Cool to < 6°C	28 days
	Radiological Parameters	3× 1-L HDPE	3000 mL	HNO_3 to pH < 2	180 days
	Total Kjeldahl Nitrogen	1-L HDPE	1000 mL	Cool to <6°C	7 days
	Alkalinity (Total, Carbonate, Bicarbonate, and Hydroxide)	250-mL	250-mL	Cool to <6°C	28 days
	TDS	250-mL HDPE	100 mL	Cool to < 6°C	7 days
	TSS	1-L HDPE	1000 mL	Cool to < 6°C	7 days

Matrix	Parameter	Container Type	Recommended Sample Volume	Preservation	Holding Time
Aqueous Equipment Blanks**	Total Organic Carbon	2x 40-mL VOA Vial	80-mL	H_2SO_4 to pH < 2, Cool to ≤ 6°C	28 days
	Total Inorganic Carbon	2x 40-mL VOA Vial	80-mL	Cool to ≤ 6°C	28 days
	Nitrate-nitrite nitrogen	250-mL HDPE	250-mL	H_2SO_4 to pH < 2	28 days

Notes:

* Volume/mass requirements for treatability testing varies depending on the test design.

** Aqueous equipment blanks are analyzed for the same parameters as the associated investigatory samples. Aqueous equipment blanks are collected in association with samples intended for chemical and radiological analyses.

G - Glass
HDPE - High Density Polyethylene
VOA - Volatile organic analysis

A.3 Field Quality Control Samples

Field quality control (QC) samples will be collected following TVA Technical Instruction ENV-TI-05.80.04 (*Field Sampling Quality Control*). Field QC samples will be collected at the frequencies specified in Table A-4 below for samples collected for chemical and radiological analyses.

Field QC samples are not required for samples collected for treatability testing, sequential extraction procedure, XRD, or acid-base accounting.

Table A-4: Field Quality Control Sample Frequency

Field QC Sample	**Aqueous Sampling Frequency**[1]	**Soil Sampling Frequency**[1]
Equipment Rinsate Blank	1 per 20 field samples	1 per 20 field samples
Field Blank	1 per sampling team per day	1 per sampling team per day
Filter Blank	1 per sampling event when dissolved parameters are collected for analysis	NA
Tubing Blank	1 per sampling event when non-certified clean/non-dedicated tubing is used for sample collection	NA
Field Duplicate	1 per 20 field samples; minimum of 1 per sampling event	1 per 20 field samples; minimum of 1 per sampling event
Matrix Spike/ Matrix Spike Duplicate (MS/MSD)[2]	1 per 20 field samples; minimum of 1 per sampling event	1 per 20 field samples; minimum of 1 per sampling event

Notes:

1 Field QC samples are not required for samples collected for treatability testing, sequential extraction procedure, XRD, or acid-base accounting.

2 MS/MSDs will be performed for parameters amenable to spiking (*e.g.,* metals, mercury, anions, and general chemistry analyses).

Field QC samples will be analyzed for the same parameters as the investigative samples (see Table A-3) with the noted exceptions.

A.4 Data Quality Objectives

As stated in the TVA-GAF-QAF, the data quality objective (DQO) process is a series of planning steps based on a scientific method to ensure that the type, quantity, and quality of environmental data used in decision-making are appropriate for the intended application. In general, DQOs provide a qualitative and quantitative framework around which data collection programs can be designed. The qualitative aspect of DQOs seeks to encourage good planning for field investigations. The quantitative aspect of DQOs involves designing an efficient field investigation that reduces the possibility of incorrect decision-making. Data quality objectives defined during planning for the NRS Treatability Study are addressed in the Work Plan and SAP.

Table A-5 provides the methods, analyte list, and reporting limits for samples collected under the Treatability Study SAP.

Table A-5: Analytes, Methods, and Reporting Limits – Groundwater Samples

Parameter	CAS No.	Method	Reporting Limit	Units
LABORATORY ANALYSES				
Chloride	7647-14-5	EPA 300.0/ SW-846 9056	1.00	mg/L
Fluoride	16984-48-8	EPA 300.0/ SW-846 9056	0.10	mg/L
Phosphate	14265-44-2	EPA 300.0/ SW-846 9056	1.00	mg/L
Sulfate	7757-82-6	EPA 300.0/ SW-846 9056	1.00	mg/L
Aluminum	7429-90-5	SW-846 6020A	0.100	mg/L
Antimony	7440-36-0	SW-846 6020A	2.00	µg/L
Arsenic	7440-38-2	SW-846 6020A	1.00	µg/L
Barium	7440-39-3	SW-846 6020A	10.0	µg/L
Beryllium	7440-41-7	SW-846 6020A	1.00	µg/L
Boron	7440-42-8	SW-846 6020A	80.0	µg/L
Cadmium	7440-43-9	SW-846 6020A	1.00	µg/L
Calcium	7440-70-2	SW-846 6020A	500	µg/L
Chromium	16065-83-1	SW-846 6020A	2.00	µg/L
Cobalt	7440-48-4	SW-846 6020A	0.5	µg/L
Copper	7440-50-8	SW-846 6020A	2.00	µg/L
Iron	7439-89-6	SW-846 6020A	50	µg/L
Lead	7439-92-1	SW-846 6020A	1.00	µg/L

Parameter	CAS No.	Method	Reporting Limit	Units
Lithium	7439-93-2	SW-846 6020A	5.00	µg/L
Magnesium	7439-95-4	SW-846 6020A	500	µg/L
Manganese	7439-96-5	SW-846 6020A	5.00	µg/L
Mercury	7487-94-7	SW-846 7470A	0.200	µg/L
Molybdenum	7439-98-7	SW-846 6020A	5.00	µg/L
Nickel	7440-02-0	SW-846 6020A	10.0	µg/L
Potassium	7440-09-7	SW-846 6020A	500	µg/L
Selenium	7782-49-2	SW-846 6020A	5.00	µg/L
Silver	7440-22-4	SW-846 6020A	1.00	µg/L
Sodium	7440-23-5	SW-846 6020A	500	µg/L
Thallium	7440-28-0	SW-846 6020A	1.00	µg/L
Vanadium	7440-62-2	SW-846 6020A	1.00	µg/L
Zinc	7440-66-6	SW-846 6020A	5.00	µg/L
pH	pH	SW-846 9040C (field measurement)	0.1	pH units
Radium-226	13982-63-3	EPA 903.0	1	pCi/L
Radium-228	15262-20-1	EPA 904.0	1	pCi/L
Radium-226+228	RA226/228	CALC	1	pCi/L
Total Dissolved Solids	TDS	SM2540C	10	mg/L
Total Suspended Solids	TSS	SM2540C	10	mg/L
Total Organic Carbon	TOC	SM5310B	1.00	mg/L
Total Kjeldahl Nitrogen	TKN	EPA 351.2	0.25	mg/L
Nitrate-nitrite Nitrogen	NO3NO2	EPA 353.2	0.10	mg/L
Sulfide	18496-25-8	SM 4500-S2F	0.10	mg/L
Alkalinity, Total	ALK	SM2320B	5.00	mg/L
Alkalinity, Carbonate	CARB	SM2320B	5.00	mg/L
Alkalinity, Bicarbonate	BICARB	SM2320B	5.00	mg/L

Parameter	CAS No.	Method	Reporting Limit	Units
Alkalinity, Hydroxide	HYDROX	SM2320B	5.00	mg/L
FIELD MEASUREMENTS				
Dissolved Oxygen	DOFLD	Field instrument	0.10	mg/L
Temperature	TEMPFLD	Field instrument	0.5	°C
Turbidity	TURB-FIELD	Field instrument	0.1	NTU
Oxidation Reduction Potential	ORP	Field instrument	1	mV
Specific Conductance	SCON	Field instrument	1	µmhos/cm
Aerated pH	PHFIELD	Field instrument	0.01	pH unit
Dissolved Carbon Dioxide	DISSCO2	Colorimetric field test kit	10	mg/L
Ferrous Iron [Fe(II)]	FE2	Colorimetric field test kit	0.02	mg/L
Sulfide	S2FLD	Colorimetric field test kit	0.01	mg/L

Notes:

ºC	-	degrees Celsius
CALC	-	parameter determined by calculation
CAS No.	-	Chemical Abstracts Service registry number
mg/L	-	milligrams per liter
mV	-	millivolts
NTU	-	nephelometric turbidity units
pCi/L	-	picocuries per liter
µg/L	-	micrograms per liter
µmhos/cm	-	micromhos per centimeter

Table A-6: Analytes, Methods, and Reporting Limits – Soil

Parameter	CAS No.	Method	Reporting Limit [1]	Units
LABORATORY ANALYSES				
Aluminum	7429-90-5	SW-846 6020A	3.00	mg/kg
Antimony	7440-36-0	SW-846 6020A	0.200	mg/kg
Arsenic	7440-38-2	SW-846 6020A	0.100	mg/kg
Barium	7440-39-3	SW-846 6020A	1.00	mg/kg
Beryllium	7440-41-7	SW-846 6020A	0.100	mg/kg
Boron	7440-42-8	SW-846 6020A	8.0	mg/kg
Cadmium	7440-43-9	SW-846 6020A	0.100	mg/kg
Calcium	7440-70-2	SW-846 6020A	50.0	mg/kg
Chromium	7440-47-3	SW-846 6020A	0.200	mg/kg
Cobalt	7440-48-4	SW-846 6020A	0.0500	mg/kg
Copper	7440-50-8	SW-846 6020A	0.200	mg/kg
Iron	7439-89-6	SW-846 6020A	5.00	mg/kg
Lead	7439-92-1	SW-846 6020A	0.100	mg/kg
Lithium	7439-93-2	SW-846 6020A	0.500	mg/kg
Mercury	7487-94-7	SW-846 7471B	0.0330	mg/kg
Magnesium	7439-95-4	SW-846 6020A	50.0	mg/kg
Manganese	7439-96-5	SW-846 6020A	0.500	mg/kg
Molybdenum	7439-98-7	SW-846 6020A	0.500	mg/kg
Phosphorus	7723-14-0	SW-846 6020A	1.0	mg/kg
Potassium	7440-09-7	SW-846 6020A	50.0	mg/kg
Nickel	7440-02-0	SW-846 6020A	0.100	mg/kg
Selenium	7782-49-2	SW-846 6020A	0.500	mg/kg
Silver	7440-22-4	SW-846 6020A	0.100	mg/kg
Sodium	7440-23-5	SW-846 6020A	50.0	mg/kg
Sulfur	7704-34-9	SW-846 6010B	100	mg/kg

Parameter	CAS No.	Method	Reporting Limit [1]	Units
Thallium	7440-28-0	SW-846 6020A	0.100	mg/kg
Vanadium	7440-62-2	SW-846 6020A	0.100	mg/kg
Zinc	7440-66-6	SW-846 6020A	0.500	mg/kg
Total Inorganic Carbon	TIC	Lloyd Kahn or SW-846 9060A	1000	mg/kg
Total Organic Carbon	7440-44-0	Lloyd Kahn or SW-846 9060A	1000	mg/kg
FIELD MEASUREMENTS				
pH	PHFIELD	Field instrument	0.01	pH unit

Notes:

CAS No. - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram

[1] Samples will be reported on a dry-weight basis; sample-specific reporting limits will vary based on sample mass, dilution factors, and percent moisture.

Table A-7 provides the specific quantitative QA objectives for chemical and radiological analyses of aqueous samples collected under the Treatability SAP.

Table A-7: Quantitative QA Objectives – Groundwater Samples

Analyte/ Parameter Group	**Method**	**Chemical Yield (%)**	**Equipment Rinsate Blank, Field Blank, Method Blank**	**LCS Accuracy (% Recovery)**	**MS/MSD Accuracy (% Recovery)**	**LCS/LCSD Precision (RPD)**	**MS/MSD Precision (RPD)**	**Laboratory Duplicate Precision (RPD)**	**Field Duplicate Precision[1]**
Metals	SW-846 6020A	NA	< RL	80-120	75-125	20	20	20	RPD < 20% difference < the RL
Mercury	SW-846 7470	NA	< RL	80-120	75-125	20	20	20	RPD < 20% difference < the RL
Anions (Chloride, Fluoride, Phosphate, Sulfate)	EPA 300.0/ SW-846 9056	NA	< RL	80-120	75-125	20	20	20	RPD < 20% difference < the RL
Total Kjeldahl Nitrogen	EPA 351.2	NA	< RL	80-120	75-125	20	20	20	RPD < 20% difference < the RL
Nitrate-nitrite Nitrogen	EPA 353.2	NA	< RL	80-120	75-125	20	20	20	RPD < 20% difference < the RL
Alkalinity (Total, Carbonate, Bicarbonate, Hydroxide)	SM2320B	NA	< RL	80-120	75-125	20	20	20	RPD < 20% difference < the RL
Total Organic Carbon	SM5310B	NA	< RL	80-120	75-125	20	20	20	RPD < 20% difference < the RL
Total Dissolved Solids	SM 2540C	NA	< RL	80-120	NA	20	NA	20	RPD < 20% difference < the RL

Analyte/ Parameter Group	**Method**	**Chemical Yield (%)**	**Equipment Rinsate Blank, Field Blank, Method Blank**	**LCS Accuracy (% Recovery)**	**MS/MSD Accuracy (% Recovery)**	**LCS/LCSD Precision (RPD)**	**MS/MSD Precision (RPD)**	**Laboratory Duplicate Precision (RPD)**	**Field Duplicate Precision[1]**
Total Suspended Solids	SM 2540D	NA	< RL	80-120	NA	20	NA	20	RPD < 20% difference < the RL
Sulfide	SM 4500-S2F	NA	< RL	80-120	75-125	20	20	20	RPD < 20% difference < the RL
Radium-226	EPA 903.0	30-110	< RL	80-120	NA	RER < 2	NA	RER < 2	RER < 2
Radium-228	EPA 904.0	30-110	< RL	80-120	NA	RER < 2	NA	RER < 2	RER < 2

Notes:

[1] When both field duplicate results are > 5× the RL, the RPD must be < 20%. When at least one result is < 5× the RL, the difference must be < the RL

LCS	-	Laboratory Control Sample
LCSD	-	Laboratory Control Sample Duplicate
MS/MSD	-	Matrix Spike/Matrix Spike Duplicate
RPD	-	Relative Percent Difference
RER	-	Relative Error Ratio

Table A-8 provides the specific quantitative QA objectives for chemical analyses of soil samples collected under the Treatability SAP.

Table A-8: Quantitative QA Objectives – Soil Samples

Analyte/ Parameter Group	Method	Equipment Rinsate Blank, Field Blank, Method Blank	LCS Accuracy (% Recovery)	MS/MSD Accuracy (% Recovery)	LCS/LCSD Precision (RPD)	MS/MSD Precision (RPD)	Laboratory Duplicate Precision (RPD)	Field Duplicate Precision[1]
Metals	SW-846 6020A	< RL	80-120	75-125	35	35	35	RPD < 35% difference < 2× the RL
Mercury	SW-846 7470	< RL	80-120	75-125	35	35	35	RPD < 35% difference < 2× the RL
Total Organic Carbon	SM5310B	< RL	80-120	75-125	35	35	35	RPD < 35% difference < 2× the RL
Total Inorganic Carbon	SM5310B	< RL	80-120	75-125	35	35	35	RPD < 35% difference < 2× the RL

Notes:

LCS	-	Laboratory Control Sample
LCSD	-	Laboratory Control Sample Duplicate
MS/MSD	-	Matrix Spike/Matrix Spike Duplicate
RL	-	Reporting limit
RPD	-	Relative Percent Difference

A.5 Laboratory Deliverables

Analytical data from TVA's contracted laboratories will be reported in Portable Document Format (.pdf) data packages and as electronic data deliverables (EDD). Data package requirements are presented in Appendix B to the TVA-GAF-QAF. EDDs will be provided in a format compatible with the project EQuIS database as described in the TVA-GAF-DMP. The required deliverables are as follows:

- Electronic data deliverables (EDDs) shall be formatted to allow for direct data upload into the project EQuIS database.
- Electronic (Portable Document Format [.pdf]) versions of Limited (Level II) data packages.
- Electronic (.pdf) versions of Full (Level IV) data packages.

The EDD and Level II deliverables shall be provided within the turn-around-time agreed to between TVA and their contracted laboratories (generally within 10 business days from sample submission). Level IV data packages will follow the Level II and EDD (generally within 20 business days from sample submission).

A.6 Data Validation/Quality Assessment

Table A-8 presents the data review frequency for chemical and radiological analysis data generated under Treatability Study SAP.

Table A-8 Data Verification and Validation Frequency

Matrix	Parameter(s)	Verification Frequency	Validation Frequency
Groundwater	All	100%	20%
Soil	All	100%	20%

A.7 Documentation, Records and Data Storage

Both field documentation and laboratory data will be generated during implementation of this investigation. AECOM will be responsible for the generation and management of field documentation and data. Eurofins TestAmerica will be responsible for receiving, analyzing and reporting chemical analytical and radiological data for this investigation. AECOM and its subcontract laboratories will be responsible for receiving, analyzing and reporting treatability study, acid-base accounting, and XRD data for this investigation. AECOM will additionally be responsible for management of data associated with treatability testing.

Field and laboratory data associated with chemical and radiological analyses will be stored in the TVA GAF project EQuIS® database which is managed by Environmental Standards. Field data will be submitted to Environmental Standards and uploaded to the project database.

Laboratory analytical data will be received from the laboratories in the format listed in Section A-5 and uploaded into the project database by Environmental Standards personnel. Analytical data generated by AECOM's treatability testing laboratory will be uploaded to an AECOM database.

A.8 Reconciliation of Data to Project Objectives

The QA Manager, in conjunction with the TVA Technical Manager, will determine whether field and validated analytical data or data sets meet the requirements necessary for decision-making. The results of measurements will be compared to the DQO requirements set forth in the project-specific SAPs. The process of reconciling project data with the DQOs will be performed with guidance from US EPA *Guidance for Data Quality Assessment, Practical Methods for Data Analysis* (February 2006).

Generally, data assessment begins with verification and validation of project data to ensure that the sampling and analysis protocols specified in the associated field Standard Operating Procedures (SOPs) and Work Plans and/or SAPs were followed, and that the measurement systems were performed in accordance with the criteria specified in these documents and this QAF. Data limitations identified during data verification and validation are communicated to the project team via reports and qualification in the project database.

Following data assessment, statistical analysis may be performed to determine whether the performance and acceptance criteria developed by the DQO planning process were achieved. As data are evaluated, anomalies in the data or data gaps may become apparent to the data users. Data that do not meet the data users' needs will be identified and appropriately noted so that decision-makers are aware of data limitations.

Data that do not meet the established DQOs may be used qualitatively or may be rejected depending on the project-specific requirements and the intended use of the data. The TVA Technical Manager, with the support of the QA Manager or designee and data validators, will assist data end users in evaluating data limitations identified and determining whether data are acceptable for their intended use.

A.9 References

US EPA. *Guidance for Data Quality Assessment, Practice Methods for Data Analysis* .US EPA QA/G-9, February 2006.

US EPA. *National Functional Guidelines for Inorganic Data Review,* October 2004.

US EPA Region 4. *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual,* November 2001.

APPENDIX B

FIELD PROCEDURES

TVA

Environmental Operations

Technical Instruction

ENV-TI-05.80.02

Sample Labeling and Custody

Revision 0001

Level of Use: Reference Use

Effective Date: 03-31-2017

Responsible Organization: Environmental Compliance and Operations

Prepared by: Diana Miles

Reviewed by: Donald W. Snodgrass Date: 03-30-2017

Concurred by: Donald E. McGee Date: 03-30-2017

Concurred by: Brian S. Fowler Date: 03-30-2017

Approved by: M. Susan Smelley Date: 03-31-2017

Revision Log

Revision or Change Number	Effective Date	Affected Page Numbers	Description of Revision/Change
0001	03-31-2017	All	Align with other environmental TIs and to incorporate specifics on Coal Combustion Residual (CCR) compliance activities.

Table of Contents

1.0 PURPOSE

This Technical Instruction (TI) provides the general technical requirements and operational guidelines for labeling of samples and the maintenance of legal sample custody through the use of Chain of Custody (COC) Records.

2.0 SCOPE

This TI applies to Tennessee Valley Authority (TVA) field sampling personnel and TVA contractors who collect environmental samples (such as surface water, groundwater, wastewater, soil, sediment, and wipe samples) for various regulatory and operational purposes.

This TI was developed based on guidance from Environmental Protection Agency (EPA), Region 4 documents (see Section 4.0, REFERENCES).

Review Cadence: This TI will be reviewed every four years, with the review documented in the Revision Log.

3.0 PRECAUTIONS/LIMITATIONS

3.1 Precautions

None

3.2 Limitations

None

4.0 REFERENCES

4.1 Performance References

A. ENV-TI-05.80.03, Field Record Keeping

B. TVA-SPP-18.005, Plan Jobs Safely

C. TVA-SPP-31.01, Records Management

4.2 Developmental References

A. ENV-TI-05.80.01, Planning Sampling Events

B. EPA, Region 4, SESDPROC-005, Sample and Evidence Management

C. EPA, Region 4, SESDPROC-011, Field Sampling Quality Control

D. EPA, Region 4, SESDPROC-209, Packing, Marking, Labeling, and Shipping of Environmental and Waste Samples

4.3 Commitments

None

5.0 PREREQUISITE ACTIONS

None

6.0 PERFORMANCE

6.1 General Considerations

A. The sections in this TI describe the procedures for sample labeling and controlling custody of samples. Any variation in these procedures is to be approved by the TVA Project Manager and is to be fully documented. Work does not progress until deviations are approved or resolved.

B. Field personnel conducting sampling activities are required to be familiar with the procedures provided in this TI and any facility-specific Sampling and Analysis Plan (SAP) and Quality Assurance Plan (QAP), as well as standard industry practices.

C. The TVA Project Manager is responsible for ensuring sampling personnel are trained and follow the instructions of this document. The TVA Project Manager is to check with the Field Team Leader regarding the equipment required, sample types and preservatives, and anticipated range of contaminant concentrations.

D. The Field Team Lead is responsible for ensuring samples are labeled correctly and for following the proper custody requirements.

6.1 General Considerations (continued)

E. Potential hazards associated with the planned field sampling tasks are to be thoroughly evaluated prior to conducting field activities. During planning and sampling activities, procedures to ensure safety will be incorporated, according to the TVA Standard Programs and Processes (SPP), TVA- SPP-18.005, Plan Jobs Safely, which provides information on using job safety analyses (JSAs) and pre-job briefings (PJBs).

F. Personnel are to wear powder-free nitrile gloves (or similar) while performing the procedures described in this TI. Specifically, powder-free nitrile gloves are worn while preparing and handling sample containers.

G. Prior to performing a sampling event, a planning document will be produced. The purpose of the planning document, as it relates to the requirements of this TI, is to document the requirements of sample containers, preservatives, hold times, required analysis, shipping arrangements, and sampling schedules. The information contained in the planning document will be utilized to generate sample labels and COC documentation to be utilized by the field personnel. COC records will be initiated, using the Earthsoft EQuIS™ Sample Planning Module (SPM), if this data management system is being utilized by the project.

H. There are two documents primarily used that describe the scope and analytical requirements of the sampling event: a facility-specific SAP and a Sample Event Planning Form (SPF). Attachment 1, Example - Sampling Event Planning Form is an example of an SPF.

6.2 Sample Identification

A. After a sampling point (e.g., monitoring well) is identified, the location is to be assigned a unique identifier, as specified by the sample planning documents (e.g., a facility-specific SAP). Refer to ENV- TI-05.80.01, Planning Sampling Events, for additional information. Each sample collected from a sampling point is then assigned a unique sample identifier (ID), in accordance with project naming conventions. Naming conventions may be specified in permits or facility-specific SAPs and/or QAPs. This Sample ID is then recorded and cross-referenced on all sample containers, custody records, and field sheets.

B. Sample IDs and labels are of critical importance in the collection of samples and in maintaining traceability from collection in the field to delivery at the laboratory and associated with final results. All information and data for a sample are keyed to its unique ID. The Sample ID and sample naming conventions are to be documented in the written sample planning documents.

6.2 Sample Identification (continued)

C. In the absence of an explicit naming convention, Sample IDs will be in the format of XXX-[MX]-[LOC]-[DATE] where:

1. XXX - Three-character plant, project, or survey identifier, **AND**
2. MX - Two-character matrix code (e.g., GW for groundwater samples, AQ for aqueous, SW for surface water), **AND**
3. LOC - Sample location (e.g., monitoring well identification number or a permitted discharge location or a river mile (RM) notation), **AND**
4. Date - The sample collection date in mmddyyyy format

D. The TVA Fossil Plant facility identification codes are listed in Table 1, Fossil Plant Facility Identification Codes.

ALF	Allen Fossil Plant
BRF	Bull Run Fossil Plant
COF	Colbert Fossil Plant
CUF	Cumberland Fossil Plant
GAF	Gallatin Fossil Plant
JSF	John Sevier Fossil Plant
JOF	Johnsonville Fossil Plant
KIF	Kingston Fossil Plant
PAF	Paradise Fossil Plant
SHF	Shawnee Fossil Plant
WBF	Watts Bar Fossil Plant
WCF	Widows Creek Fossil Plant

Table 1, Fossil Plant Facility Identification Codes

6.2 Sample Identification (continued)

E. Sample IDs are to be recorded and/or cross-referenced in field logbooks, field notebooks, or on field sheets, on COC forms, and recorded on sample labels, in accordance with ENV-TI-05.80.03, Field Record Keeping. Field data and results of laboratory analyses are referenced to and reported using these sample IDs. Information about station location, date and time of collection, and name of sample collector must be traceable to the original field sheet. When available and deemed appropriate, electronic devices (e.g., laptop computers, electronic tablets, etc.) may be used in lieu of logbooks, field sheets, and other paper forms for data collection and transmission and recording other relevant information.

6.3 Pre-Field Preparation

A. Obtain COC records and sample labels.

B. Prior to field sampling events, ensure sample labels and custody forms are completed, as much as possible, with information from the sample planning documents.

C. If labels are to be completed in the field, ensure labels are large enough to allow the Field Team to record the label information.

6.3.1 Sample Custody

NOTE

Locking samples in a TVA-owned or work vehicle is considered a designated secure area, but the use of custody seals on individual containers, as well as sample coolers, is required.

A. Sample custody is maintained when a sample is:

1. In the actual possession of the Sampler/Sampling Team/Sample Custodian, **OR**
2. In the view of the sampler after being in physical possession, **OR**
3. Custody-sealed and secured to prevent tampering, **OR**
4. Placed in a designated secure area

6.3.1 Sample Custody (continued)

B. The following three components are required to demonstrate sample integrity and maintain custody:

1. Sample Identification: An adhesive (stick-on) label or tag is completed with the unique sample identification number and placed on each sample container. Waterproof, non-erasable ink is required for completing sample labels.

NOTE

It is strongly urged that seals be placed on both the sample container and shipping container.

2. Sample Seals: A custody seal with the date and initials of the sampler is to be placed on the sample container in such a manner that tampering with the sample is evident (e.g., across the lid and touching the glass on both sides of a sample jar) or on a storage or shipping container (such as a cooler) in such a manner that the container cannot be opened without damaging the seal. Custody seals are to be placed in a position that it will be apparent if the seals have been disturbed (i.e., remnants of the seal left in place or ink or residue present where seal was removed).

Step 6.3.1B.3 Applies to CCR Only

3. Coal Combustion Residual (CCR) compliance activities require that seals be placed on both the sample container and shipping container.

4. COC Record: The field COC Record is used to document the custody of all samples from collection until they are sealed in a storage or shipping container or delivered to the analytical laboratory. The COC Record documents custody and transfer of samples from the collector (or custodian) to another person, to the laboratory, or to another organizational element. The COC Record also serves as a sample logging mechanism for the laboratory sample custodian. A separate COC Record is to be used for each final destination or laboratory receiving samples.

6.4 Chain of Custody (COC) Record Requirements

Complete the COC Record by recording all information necessary to accurately and completely document the sample collection and the required analyses (in the appropriate spaces) for each laboratory that will receive samples (see Attachment 2, Example - Chemistry Chain of Request and Custody Record). Pre-printed (multi-carbon) forms filled out by hand are permitted, as are computer-generated forms with sample IDs for planned samples printed on them. The COC Record must be completed as samples are collected following the requirements described below:

A. Prior to signing the COC Record, a review consisting of the following should be made.

   1. Are all samples listed in the sampling plan included on the COC?

   2. Are the sampling ID numbers accurate, including format?

   3. Does the location code included in the sample ID match the location code listed in the location field of the COC and the information listed in the sampling plan?

   4. Is the sample matrix code consistent with the information listed in the sampling plan?

   5. Are any planned QA/QC samples properly identified?

   6. Has the chemical analysis been properly requested/identified in accordance with the SAP and QAP?

B. Any corrections to the COC will be made in accordance with ENV-TI-05.80.03, Field Record Keeping. If necessary, a revised COC will be prepared to address comments and/or correct any errors identified during the review.

C. Field Team Lead (if a sampling team) or sample collector must sign in the designated signature block. For sampling teams, record the name of each Field Team member.

D. One sample should be recorded on each line of the COC Record and not be split among multiple lines.

E. If multiple Field Teams are collecting samples, the Field Team Lead or sample collector will generate one COC Record for their Field Team.

F. The total number of sample containers collected for each sample ID must be recorded in the appropriate column. Required analyses are to be entered in the appropriate location on the COC Record.

6.4 Chain of Custody (COC) Record Requirements (continued)

G. The field sample custodian, Field Team Lead, or other designee, and subsequent transferees are to document the transfer of the samples listed on the COC Record using the following process. Both the person relinquishing the samples and the person receiving them must sign the form. When the form makes reference to affiliation (e.g., contractor or organization), that information must also be recorded. The date and time of transfer are to be documented in the proper space on the COC Record. NOTE: the exception to this requirement would be when packaged samples are shipped with a common carrier (e.g., FedEx or UPS). Even though the common carrier receives the samples, the courier will not sign. The shipping container or internal sample containers (or both) MUST be sealed at this juncture for custody to be maintained. The COC record is to be sealed inside the cooler.

H. The last person receiving the samples will be the laboratory sample custodian or receiving function.

I. The laboratory sample custodian will document the custody transfer by signing and dating the COC Record with the date and time that custody is received. The COC Record is a uniquely identified document. Once the COC Record is completed, it becomes a project record document and must be maintained in the project files. A copy of the outgoing COC Record is to be maintained in the project files. Completed records are to be obtained from the laboratory and maintained in the project files.

J. The suitability of any other form for use to document COC will be approved by the TVA Project Manager, if necessary. If another form is approved to be used to document COC, it is to be compared against the above information to ensure that the required custody information is recorded in a legible format.

K. If a sample container is opened or re-sealed, the Field Team Leader or designee must record all of these actions in the field logbook or field notebook, and a new custody seal must be applied Electronic means of recording these actions may be used.

L. Once a sample is placed in a properly sealed container for shipment to a laboratory or storage area, custody is maintained and no further RELINQUISHED BY and RECEIVED BY signatures are required until the container is opened (usually at the receiving laboratory).

6.4.1 Transfer of Custody with Shipment

M. All sample coolers must be accompanied by a laboratory COC Record that is to be taped to the inside lid of the cooler in a re-sealable bag. If multiple coolers are needed for a shipment pertaining to a single COC Record, it is required that copies of the COC Record are to be included in the second and subsequent shipping coolers along with annotations in the field comments section, describing the number of coolers involved with that COC Record.

N. The RELINQUISHED BY portion of the COC Record is to be signed by the field sample custodian and the RECEIVED BY portion is to be signed by the laboratory sample custodian when the shipment is opened.

6.4.2 Loss of Custody

A. Loss of custody occurs when samples show any evidence of tampering, such as:

1. Broken custody seals on sample containers
2. Broken custody seals on shipping containers (when the interior samples do not have intact custody seals)
3. Cuts to plastic bags containing samples
4. Removal or loss of Sample ID tags or labels
5. Illegible Sample ID tags or labels

B. If any of these occur, the samples are considered to have failed to maintain sample custody.

C. However, should a shipping container be misplaced during shipment, be mis-delivered, or otherwise delayed, custody will have been maintained if the container is eventually found with either shipping container custody seals intact or sample container custody seals intact.

6.5 Field Logbooks and Data Sheets

Field logbooks or, when appropriate, the COC Record, documenting daily activities, including sample collection and tracking information, are to be maintained by the Field Team Lead or designee, and are an important tool in documenting sample custody. Electronic means of recording these actions may be used. When electronic means are not used, information is to be recorded into the field logbook by the Field Team Leader or designee using waterproof, indelible ink. Logbook guidelines provided in ENV-TI-05.80.03, Field Record Keeping and TVA-SPP-31.01, Records Management are to be followed when recording information, observations, and measurements in field logbooks or field notebooks.

7.0 POST PERFORMANCE ACTIVITY

None

8.0 RECORDS

Records generated in the process of performing the activities in this TI must be processed and maintained as stated in the Environmental Records Matrix, in accordance with the TVA Document Services Records Management procedures.

8.1 Quality Assurance Records

A. Chain of Custody forms

B. Field logbooks, or field notebooks

8.2 Non-Quality Assurance Records

Groundwater Sampling Equipment and Materials Checklist

Attachment 1
(Page 1 of 3)

Example - Sampling Event Planning Form

Example - Sampling Event Planning Form Attach Relevant Files to this Document	
Initiated by (Name/Organization)	
Date/Time Form Completed	
Project/Site ID	
Who is making the request to collect samples (name/organization)?	
Date/time request was made?	
What media will be sampled?	
Context of request - Why are the samples being collected?	
Are there any applicable sampling plans or sampling requirements for the collection of the samples? If so, attach the plan/requirements.	
Intended use of date - For what purpose will the data be used?	
Sampling locations and number of samples anticipated to be collected.	
Participating organizations for sample splits, if applicable.	
Will site sampling personnel be required to assist in sampling event?	
What sampling supplies are required for the sampling effort?	
Are supplies required? Where (person/address)/when should supplies be shipped?	

Attachment 1
(Page 2 of 3)

Example - Sampling Event Planning Form

Example - Sampling Event Planning Form **Attach Relevant Files to this Document**	
Initial receiving lab or storage/prep location, if arranged by initiator of form.	
Laboratories performing analysis if arranged by initiator of form.	
Ship to name/address for sample shipment.	
Estimated sampling date/time.	

Analytes	Preparatory Method	Analytical Method	Required Detection Limits

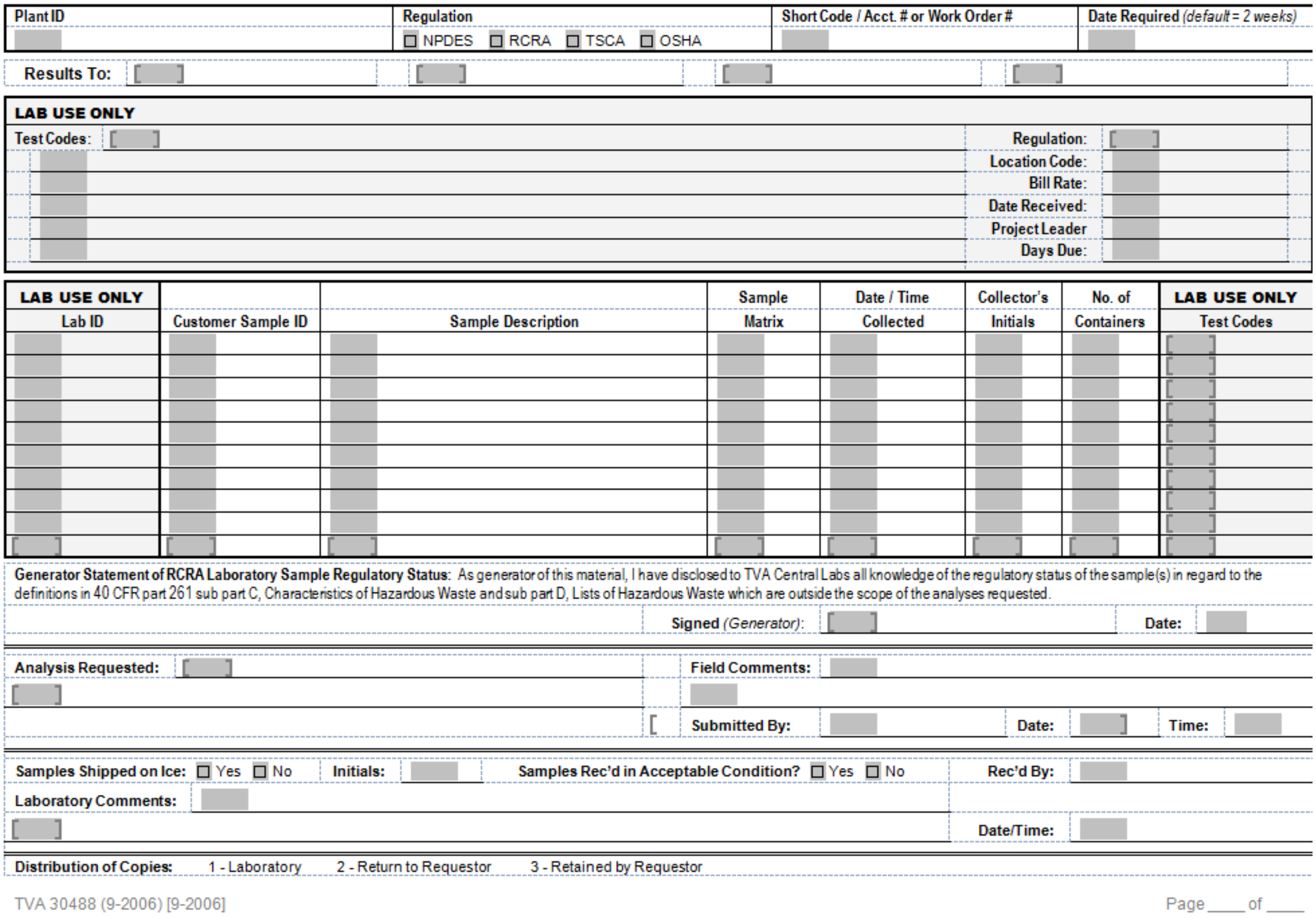
Attachment 1
(Page 3 of 3)

Example - Sampling Event Planning Form

Analyte (in groups in accordance with laboratory instructions)	**Container Type**	**Preservative**	**Volume**
Actual Sampling Date			
Actual Samples Collected			
Deviations from Plan			
Shipping Method			
Expected Data Delivery from Laboratories			
Reporting Requirements			
Sampling Notes			

Attachment 2
(Page 1 of 1)

Example - Chemistry Chain of Request and Custody Record



Plant ID	Regulation	Short Code / Acct. # or Work Order #	Date Required *(default = 2 weeks)*
	☐ NPDES ☐ RCRA ☐ TSCA ☐ OSHA		

Results To:

LAB USE ONLY

Test Codes:

Regulation:
Location Code:
Bill Rate:
Date Received:
Project Leader
Days Due:

LAB USE ONLY Lab ID	Customer Sample ID	Sample Description	Sample Matrix	Date / Time Collected	Collector's Initials	No. of Containers	LAB USE ONLY Test Codes

Generator Statement of RCRA Laboratory Sample Regulatory Status: As generator of this material, I have disclosed to TVA Central Labs all knowledge of the regulatory status of the sample(s) in regard to the definitions in 40 CFR part 261 sub part C, Characteristics of Hazardous Waste and sub part D, Lists of Hazardous Waste which are outside the scope of the analyses requested.

Signed *(Generator)*: **Date:**

Analysis Requested:

Field Comments:

Submitted By: **Date:** **Time:**

Samples Shipped on Ice: ☐ Yes ☐ No **Initials:** **Samples Rec'd in Acceptable Condition?** ☐ Yes ☐ No **Rec'd By:**

Laboratory Comments:

Date/Time:

Distribution of Copies: 1 - Laboratory 2 - Return to Requestor 3 - Retained by Requestor

TVA 30488 (9-2006) [9-2006]

Page ____ of ____

Environmental Operations

Technical Instruction

ENV-TI-05.80.03

Field Record Keeping

Revision 0000

Level of Use: Reference Use

Effective Date: 03-31-2017

Responsible Organization: Environmental Compliance and Operations

Prepared by: Diana Miles

Reviewed by: Donald W. Snodgrass Date: 03-30-2017

Concurred by: Donald E. McGee Date: 03-30-2017

Concurred by: Brian S. Fowler Date: 03-30-2017

Approved by: M. Susan Smelley Date: 03-31-2017

Revision Log

Revision or Change Number	Effective Date	Affected Page Numbers	Description of Revision/Change
0000	03/31/17	All	Initial issue

Table of Contents

1.0 PURPOSE

This technical instruction (TI) specifies documentation requirements to ensure that sample collection and field measurement activities will be traceable through field records. Documentation must be maintained to trace the standardization/calibration of instrumentation, possession and handling of samples from the time of collection through submittal to the laboratory, to allow sampling locations to be located in the future, to record sampling methods and equipment, and to identify field personnel responsibilities, among other important information. Field documentation procedures are important both from a technical and a legal perspective.

2.0 SCOPE

A. This TI applies to all TVA employees and contractors involved in sample collection and field measurement activities.

B. The procedures described in this TI are applicable to field data collection media such as logbooks, log sheets, instrument logbooks, sample labels, and Chain of Custody documentation. Guidance is also provided in TVA-SPP-31.01, Records Management.

Review Cadence: This TI will be reviewed every four years with the review documented in the Revision Log.

3.0 PRECAUTIONS/LIMITATIONS

3.1 Precautions

None

3.2 Limitations

None

4.0 REFERENCES

4.1 Performance References

A. TVA-SPP-31.01, Records Management

B. ENV-TI-05.80.02, Sample Labeling and Custody

4.2 Developmental References

A. EPA, A Compendium of Superfund Field Operations Methods, Office of Solid Waste and Emergency Response. Directive 9355.0-14, 1987 (http://www.hanford.gov/dqo/project/ level5/Sfcompnd.pdf).

B. EPA, Compliance-Focused Environmental Management System - Enforcement Agreement Guidance, National Enforcement Investigations Center, EPA-330/9-97- 002R, 2005 (http://www.epa.gov/oecaerth/resources /policies/neic/cfems_05.pdf).

C. EPA, Contract Laboratory Program Guidance for Field Samplers, Office of Superfund Remediation and Technology Innovation, OSWER 9240.0-47, EPA 540- R-09-03, January 2011 (http://www.epa.gov/superfund/programs/clp/ download/sampler/CLPSamp-01-2011.pdf).

D. EPA, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Solid Waste and Emergency Response. Directive 9355.3- 01, 1988 (http://www.epa.gov/superfund/policy/remedy/ pdfs/540g-89004-s.pdf).

E. EPA, Guidance for Performing Preliminary Assessments Under CERCLA. Office of Solid Waste and Emergency Response, Directive 9345.0-01A, 1991 (http://www.epa.gov/superfund/sites/npl/hrsres/#PA%20Guidance).

F. EPA, Guidance for Performing Site Inspections Under CERCLA, Office of Solid Waste and Emergency Response, Directive 9345.1-05, 1991 (http://www.epa.gov/ superfund/sites/npl/hrsres/#PA%20Guidance).

G. EPA, Region 4, Logbooks–Operating Procedure, SESDPROC-010 (http://www.epa.gov/region4/sesd/fbqstp/Logbooks.pdf).

H. EPA, Region 4, Field Sampling Quality Control, SESDPROC-011 (http://www.epa.gov/region4/sesd/fbqstp/).

4.3 Commitments

None

5.0 PREREQUISITE ACTIONS

None

6.0 PERFORMANCE

6.1 General Considerations

Proper documentation of field activities is a crucial part of the field investigation and remediation process. This TI describes the actions and protocols for field data entry into the field data collection media. These protocols are not typically discussed in recent regulatory guidance concerning field investigation activities because they were addressed in detail during early policy development periods of the environmental industry. Some examples of the early Environmental Protection Agency (EPA) publications that address field documentation are listed in the following. The complete references for EPA documents are provided in Section 4.0.

A. A Compendium of Superfund Field Operations Methods

B. Compliance-Focused Environmental Management System - Enforcement Agreement Guidance

C. Contract Laboratory Program Guidance for Field Samplers

D. Guidance for Conducting Remedial Investigations and Feasibility Studies Under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

E. Guidance for Performing Preliminary Assessments Under CERCLA

F. Guidance for Performing Site Inspections Under CERCLA

G. Logbooks - Operating Procedure (EPA, Region 4)

H. Field Sampling Quality Control (EPA, Region 4)

This TI describes the procedures for field documentation. Any variation in these procedures must be approved by the TVA Project Manager and Quality Assurance (QA) Officer and be fully documented. Field work cannot progress until deviations are approved or resolved.

6.2 Field Logbook

A. Facility-specific, water-proof, dedicated logbooks, or other appropriate field notebook, will be used for major projects and by each sampling team associated with a major project. Logbook entries should be objective, factual, and free of personal feelings or other terminology which might prove inappropriate or subjective. Aspects of sample collection and handling, as well as visual observations, are to be documented at the time of sample collection.

B. Documentation for sampling and field measurements of events, which are limited in scope with a small number of samples, such as the sampling of an oil drum, or those of a routine nature, will be maintained in the sampler's/technician's field notebook or other means deemed appropriated by the TVA Project Manager.

C. Each field team conducting sampling activities is to maintain a field logbook/notebook to document the activities conducted by the field team every day that field work is conducted. At a minimum, Section 6.2C should be recorded, when pertinent:

1. Project name, project location, project identifier, project leader's full name, TVA Project Manager or Field Team Lead's name and initials, field team members' names and initials, usually on first page. Include company or organizational affiliations and responsibilities of individuals listed.

2. Name and location of the site, such as STATION IDENTIFICATION.

3. Date(s) of sample collection or event.

4. Daily time of arrival to the site.

5. Daily weather conditions, such as temperatures, wind, ice, snow, and rain, including significant changes to weather conditions.

6. Pertinent field observations that may adversely impact sample quality, such as smoke, dust, or the presence of heavy equipment.

7. Daily summary of equipment preparation procedures, if appropriate. If equipment preparation and calibration were performed on a previous day, this information also is to be included in the daily entry on the day equipment was used. If a separate logbook is used to document equipment preparation and calibration, a reference to this logbook is to be included in the daily entry the equipment is used.

8. Time of sample collection.

9. Numbers and types of samples collected with respective sample identification numbers.

6.2 Field Logbook (continued)

10. Numbers and types of sample containers and preservation (including ice).
11. Description of sampling methodology by reference to the sample planning documents and specific TIs.
12. Specific sampling characteristics, such as collection depth, color or oder of sample, temperature, or turbidity.
13. Physical description and/or sketch of the sample collection location(s), maps, and applicable process diagrams.
14. Global Positioning System (GPS) data, if applicable.
15. Record of daily phone calls and/or contact with individuals or customers at the sampling site, during the day's sampling events, that are directly related to sample collection.
16. Generation management or disposal of investigation-derived wastes, including the source of each waste stream generated.
17. Location of electronic data file backups, if applicable.

D. Key instructions of field documentation, described in Section 4.0, and other pertinent documents are provided below:

1. Ensure logbooks are bound.
2. Consecutively number each page of the logbook.
3. Reserve the first one to three pages of a logbook for a table of contents, which is completed as the logbook is filled.
4. Record chronological entries in the logbook so that a time notation introduces each entry.
5. Use only indelible ink for logbook entries.
6. Record data directly and legibly in the field logbook.
7. Line out errors in the logbook (a single line strike-through) and initial and date the correction. The incorrect material is not to be erased, made illegible, nor obscured so that it cannot be read.
8. Avoid leaving any blank line(s) between logbook entries. Cross out any blank spaces that exist with a single line, including blank space at the end of the line containing an entry, and initial and date the cross out.

6.2 Field Logbook (continued)

9. The field team member completing the field logbook is to sign and date each page of the logbook.

10. If pre-printed, adhesive labels are used in logbooks or bound forms to facilitate organization of information entry, sign the label with the signature beginning on the label and ending on the page of the logbook such that the label cannot be removed without detection.

11. Upon completion of the daily field activities, indicate clearly the end of the project entries in the logbook and/or bound forms by recording END on the last page of notes, and dating and initialing the notation.

12. In order to demonstrate continuity of the project and to preclude questioning of the integrity of the data collection process, do not remove pages from bound logbooks and forms under any circumstances.

E. When maps, machine printouts, photocopies, and other documents are to be included in a logbook, a permanent adhesive is to be applied. The initials, date, and time of inclusion are to be noted in such a manner that the notation begins on the inserted material and ends on a logbook page.

F. When field measurements are conducted, the following are to be recorded in the field logbook/notebook, as applicable:

1. References, such as applicable TIs.

2. Date and time of measurement or deployment.

3. Sample and station identification, as appropriate.

4. Reference to equipment type, model number and equipment identifier.

5. Manufacturer name, lot number, and expiration date for all buffers and standardization/calibration standards unless included in a separate standardization/calibration logbook or on a standardization data form, in which case a reference to the standardization/calibration logbook or standardization data form is to be included.

6. Standardization/calibration information including pre- and post-sampling calibration readings, unless included in a separate calibration logbook or on a standardization data form, in which case a reference to the standardization/calibration logbook or standardization data form is to be included.

7. Details on deployment; time of deployment and retrieval, depth and total depth, when applicable.

6.2 Field Logbook (continued)

8. Identifier for ancillary equipment, such as phone modems.
9. Time of deployment and retrieval for deployed equipment.
10. Physical description of matrix.
11. Duties of sample team members, such as calibration, collection, deployment, retrieval, as applicable.
12. Measurements or readings for non-logging devices unless included in a separate field data sheet, in which case a reference to the field data sheet is to be included.
13. GPS coordinates for non-logging devices.
14. Location of electronic data file backups, where applicable.
15. Ambient air temperature, where applicable to evaluating field data.
16. Conditions that may adversely affect quality of measurements, such as ice, temperature extremes, or algal growth.
17. Maintenance performed, if not recorded in a separate maintenance logbook.
18. Meter or device malfunctions, when applicable.

G. The Field Team Lead and/or designee will review the field logbook entries on a weekly basis at a minimum (daily review is preferred) for completeness and accuracy and indicate this review by initialing the entries. At this time, the logbook pages should be scanned into a digital format, as described in Section 6.5

H. If field logbook review indicates that corrections are necessary, the corrections are to be made by the person who originally recorded the entries into the logbook. Corrections are to be initialed and dated with the date that the corrections were entered. If there is insufficient space on the page where correction is required, the correction will be made on an available blank page of the field logbook with a reference to the page where the correction was required. The page where the correction was entered will be noted on the original page where the correction was required and the entry initialed and dated.

6.2 Field Logbook (continued)

I. In cases where the logbook does not have available blank pages for entry of the correction, the correction is to be documented in a subsequently numbered logbook and a note is to be included on the original page where the correction was required indicating the logbook number, including page number, where the correction is documented. Continuation in a non-sequential manner, such as to later pages in the same logbook or to a later logbook in that sequence, will include back-reference to the location of the beginning of the entry.

J. Corrections added to subsequent logbooks will also indicate the page and the number of the logbook and where the correction was required.

6.3 Field Data Forms

The use of field data forms may be appropriate for the collection of some types of field data, such as groundwater stabilization data, ENV-TI-05.80.42, Groundwater Sampling, or daily equipment calibration information, ENV-TI-05.80.46, Field Measurement Using a Multi-Parameter Sonde. While the use of field data forms is permitted, they are not to be used to replace a field logbook. When field data forms are used, an entry will be made in the project field logbook, indicating additional information is available on a field data form. The reference to the field data form in the field logbook will include the name of the field data form, the date of completion, and other distinguishing information, such as well identification number or equipment serial number. Information recorded on field data forms is to be done so in accordance with the requirements of this TI.

6.4 Records of Sampling Containers, Equipment, and Gloves

Upon receipt, sample vials/containers and gloves are to be placed in a suitable clean and secured storage location. A record is to be kept of the lot numbers for each shipment received. Records of lot testing provided by the manufacturer are to be kept in project files. All stored/cleaned equipment (such as cleaned and wrapped in aluminum foil or other suitable protection and then stored prior to use at a later date) will be marked with the date on which preparation was completed prior to being placed in storage. Suitable instrument-specific logbooks are to be maintained to document cleaning when such cleaning is not documented in a field logbook.

6.5 Field Records Management

Records associated with field sampling are to be managed in accordance with TVA-SPP-01, Records Management, and as follows:

A. In addition to the original Chain of Custody (COC) Record that accompanies each sample shipment, an electronic copy of each COC form is to be provided in the project files. Refer to ENV-TI-05.80.02, Sample Labeling and Custody. A working copy of the COC is to be retained in working files in the field sampling work area by the Field Team lead for reference. The TVA Project Manager or Field Team Lead will maintain a list of people requiring courtesy copies of the COC forms. Courtesy copies may be distributed by either hard copy (mail) or electronic copy (email) and have to be distributed the next working day after sample collection, when the completed COC Record is submitted to the project files.

B. The receiving laboratory is to provide a completed copy of the COC record as part of the data deliverables or as part of routine sample receipt notification, usually by email. An electronic copy released as part of data deliverables will become part of files. Any electronic copy may be printed and retained by the Field Team Lead in the field for reference, such as a cross-reference to the laboratory identifier.

C. Field logbooks are to have a unique identifier and are to have pre-numbered pages. Newly-completed and reviewed pages of logbooks are to be electronically copied to the project files on a weekly basis so that loss or accidental destruction in the field will result in in a minimum of lost data. The copies are to be reviewed to ensure they are entirely legible.

D. Filled logbooks, once completely electronically duplicated to files, are to be retained by the field team. The field logbook copy becomes the primary record, and the filled original field logbook becomes a working copy. At the end of the active reference, the field logbooks are to also be filed in files.

7.0 POST PERFORMANCE ACTIVITY

None

8.0 RECORDS

Records generated in the process of performing the activities in this TI must be processed and maintained as stated in the Environmental Records Matrix, in accordance with the TVA Document Services Records Management procedures.

8.1 Quality Assurance Records

A. Chain of Custody forms

B. Field logbooks or field notebooks

8.2 Non-Quality Assurance Records

None

Environmental Operations

Technical Instruction

ENV-TI-05.80.04

FIELD SAMPLING QUALITY CONTROL

Revision 0001

Level of Use: Reference Use

Effective Date: 09-16-2019

Responsible Organization: Environmental Compliance and Operations

Prepared by: Environmental Compliance and Operations

Reviewed by: Donald W. Snodgrass Date: 08-27-2019

Concurred by: Jim Osborne Date: 08-28-2019

Concurred by: Brian S. Fowler Date: 08-28-2019

Approved by: M. Susan Smelley Date: 09-09-2019

Revision Log			
Revision or Change Number	**Effective Date**	**Affected Page Numbers**	**Description of Revision/Change**
0000	03/31/17	All	Initial issue
0001	09/16/2019	All	Removed CCR information; other changes throughout.

Table of Contents

1.0 PURPOSE

This Technical Instruction (TI) provides the general technical requirements and operational guidelines for the proper collection and documentation of field quality control (QC) samples. The requirements of this TI are applicable to field blanks, equipment rinsate blanks, field duplicate samples, matrix spike/matrix spike duplicate (MS/MSD), and certain other QC sample types (performance evaluation [PE] samples, split-samples, sample preservative blanks, temperature blanks, and on-site potable decontamination water system blanks) are provided.

2.0 SCOPE

A. This TI applies to all Tennessee Valley Authority (TVA) employees and contractors involved in sample collection and field measurement activities.

B. This TI describes the requirements associated with field QC sampling. Standard analytical QC checks that should be instituted by field personnel, include the following:

1. Field blanks
2. Equipment rinsate blanks
3. Field duplicate samples
4. MS/MSD samples
5. Filter blanks
6. Tubing blanks

C. The Quality Assurance Project Plan (QAPP), facility-specific Sampling and Analysis Plan (SAP), or customer may define the collection frequency and type of QC samples that will be collected that differ from the information in this TI.

Review Cadence: This TI will be reviewed every four years, with the review documented in the Revision Log.

3.0 PRECAUTIONS/LIMITATIONS

3.1 Precautions

None

3.2 Limitations

None

4.0 REFERENCES

4.1 Performance References

A. ENV-TI-05.80.01, Planning Sampling Events

B. ENV-TI-05.80.02, Sample Labeling and Custody

C. ENV-TI-05.80.03, Field Record Keeping

D. ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination

E. ENV-TI-05.80.06, Handling and Shipping of Samples

F. ENV-TI-05.80.43, Water Sampling for VOC Analysis

G. ENV-TI-05.80.51, Soil Sampling for VOC Analysis

H. TVA-SPP-31.01, Records Management

4.2 Developmental References

US EPA, Region 4, SESDPROC-011-R5, Field Sampling Quality Control, 2017

4.3 Commitments

None

5.0 PREREQUISITE ACTIONS

None

6.0 PERFORMANCE

6.1 General Considerations

A. Quality assurance (QA) will be verified by maintaining site logs, by documenting field activities in a field logbook or notebook, and by collecting and analyzing quality control (QC) samples. QC samples will be used to assess laboratory and field team performance and to gauge the likelihood of cross-contamination associated with both field and laboratory activities. QC samples will be collected and analyzed in conjunction with scheduled investigative samples using EPA methods.

B. The QC samples and associated frequencies presented in this TI are to be used as guidance in the absence of project-specific sample planning documents which may further specify QC sample types or frequencies. Project guidance documents, including sample planning documents, facility-specific SAP or QAPP, and applicable TIs, are to be reviewed prior to initiating field activities to determine QC sampling requirements. Any variation in these procedures must be approved by the TVA Project Manager or QA staff and be fully documented.

C. Unless otherwise specifically stated by the Quality Assurance Plan (QAP) or Sampling and Analysis Plan (SAP), and at the discretion of the field team leader, reagent-grade, deionized, or distilled water may be substituted for one another in preparing QC sample.

D. Field work must be properly documented. Depending on the requirements of your organization, there are different mechanisms for recording. You must meet the requirements for your specific organization.

1. Groundwater Application, or other electronic data collection system
2. Field logbooks
3. Field worksheets (see Attachment 1, Example - Preliminary Groundwater Data Field Worksheet)
4. Field notebooks
5. Data sheets

E. Review Job Safety Analysis (JSA) Worksheet – Form 15943 and identify needed safety equipment. Conduct a Pre-Job meeting prior to beginning work and document on the Pre-Job Brief Checklist – Form 40898.

F. Once the work activities are complete conduct a post-job meeting and document the meeting using the Post-Job Review Checklist - Form 40899.

G. Refer to Attachment 1, Definitions.

6.2 Field Blanks

A. Field blanks are used to assess the potential for cross-contamination during the sampling process due to ambient conditions and to validate the cleanliness of sample containers. The collection of field blanks is recommended, if known or suspected sources of contamination are located within close proximity to the sampling activities or if field instruments indicate the presence of contamination above background levels. Field blank samples are to be collected and analyzed for the parameters identified in the QAP and/or the facility specific SAP.

B. Field blanks are to be collected, as defined below, at a rate of one field blank per sampling team per day.

1. Collect field blanks by pouring laboratory-supplied deionized (DI) water into appropriate certified clean, laboratory-specified, preserved, if necessary, containers as close to the sample collection site as is reasonable. Field blank samples are to be labeled as specified in ENV-TI-05.80.02, Sample Labeling and Custody.

2. After sample collection, properly seal the containers and place upright in an iced sample cooler within 15 minutes of sample collection, as specified by ENV-TI-05.80.02, Sample Labeling and Custody, and ENV-TI-05.80.06, Handling and Shipping of Samples.

3. Ship the field blanks with the associated investigative samples to the analytical laboratory.

6.3 Equipment Rinsate Blanks

A. Equipment rinsate blanks are used to assess the effectiveness of field equipment decontamination procedures for minimizing the potential for cross-contamination between samples and to assess the cleanliness of reusable, dedicated and new disposable equipment. At the discretion of the TVA Project Manager, equipment rinsate blanks may not be required when new, certified-cleaned, dedicated, or disposable sampling equipment is used. When collected, the minimum frequency is one equipment rinsate blank per matrix per 20 samples collected or once per sampling event, whichever is more frequent; however, the appropriate project control documents should be referenced to assess project-specific frequencies. An equipment rinsate blank sample is to be collected when the tubing or bladder is changed on a dedicated pump, or after any maintenance is performed on dedicated pumps, as described in ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination and ENV-TI-05.80.21, Monitoring Well Inspection and Maintenance.

6.3 Equipment Rinsate Blanks (continued)

B. Equipment rinsate samples are to be analyzed for the parameters identified in the QAP and/or the facility specific SAP.

1. Collect equipment rinsate blanks by pouring laboratory-supplied DI water into, pumping through, and/or pouring over clean and properly decontaminated sampling equipment. Refer to ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination, for cleaning and decontamination instructions. Equipment rinsate blanks are to be labeled, as specified, in ENV-TI-05.80.02, Sample Labeling and Custody.

2. Collect and containerize the rinsate that has contacted the sampling equipment in appropriate certified clean, laboratory-supplied preserved, if necessary, containers.

3. After sample collection, seal the containers properly and place upright in an iced cooler within 15 minutes of sample collection, as specified by ENV-TI-05.80.02, Sample Labeling and Custody, and ENV-TI-05.80.06, Handling and Shipping of Samples.

4. Ship the equipment rinsate blank with the associated investigative samples to the analytical laboratory.

6.4 Field Duplicate Samples

A. Field duplicate samples are used to assess the reproducibility of laboratory analytical results, field sampling, or variability of a sampling matrix. Field duplicates are to be collected and submitted to the laboratory as BLIND samples labeled with the project-designated nomenclature, as specified in ENV-TI-05.80.02, Sample Labeling and Custody. Field duplicate samples are to be analyzed for the parameters identified in the QAP and/or the facility specific SAP.

B. Duplicate samples are to be collected simultaneously with the investigative sample. If the duplicate can not be collected simultaneously with the investigate sample, this should be noted in the field logbook. The minimum frequency is one field duplicate sample for every 20 investigative samples per matrix type, or once per sampling event. The procedures for collecting duplicate samples in soil/sediment and aqueous media are stipulated as follows:

6.4 Field Duplicate Samples (continued)

1. Prior to collecting investigative and duplicate soil/sediment samples for non-volatile organic parameters, composite and homogenize the sample material. Alternately fill the investigative and duplicate sample container by thirds from the homogenized material until both sets of containers are filled. Collect duplicate samples one parameter at a time. Duplicate samples for volatile organic parameters shall be collected as close to the location of the investigative sample as possible.

2. For aqueous samples for non-volatile organic parameters, alternately fill by thirds the investigative sample and duplicate sample containers until both sets of containers are filled. If a temporary transfer container is being used for aqueous sample collection, agitate the sample between filling each third, at a minimum, to help keep the sample homogenized. Collect duplicate aqueous samples one parameter at a time.

3. Duplicate sample containers for volatile organic parameters should be filled completely (i.e., not in thirds) and collected immediately after the investigative sample. Temporary transfer containers are not to be used when collecting volatile organic parameter samples.

4. After sample collection, seal the containers properly and place upright in an iced cooler within 15 minutes of sample collection, as specified by ENV-TI-05.80.02, Sample Labeling and Custody, and ENV-TI-05.80.06, Handling and Shipping of Samples

5. Ship the equipment field duplicate samples with the associated investigative samples to the analytical laboratory.

6.5 Matrix Spike/Matrix Spike Duplicate (MS/MSD) Samples

A. MS/MSD samples are investigative samples, usually for organic analysis, to which known amounts of compounds are added in the laboratory before extraction and analysis. The recoveries for spiked compounds can be used to assess how well the method used for analysis recovers target compounds in the site-specific sample matrices. The minimum frequency is one set of MS/MSD samples for every 20 investigative samples per matrix type, or once per sampling event, whichever is more frequent; however, the appropriate project control documents should be referenced to assess project-specific frequencies.

1. Collect MS/MSD samples by collecting a triple volume of an investigative sample.

2. Prior to collecting investigative and MS/MSD soil/sediment samples for non-volatile organic parameters, composite and homogenize soil/sediment. Alternately fill the investigative and MS/MSD sample containers by thirds from the homogenized material until all three sets of containers are filled. Collect MS/MSD samples one parameter at a time. MS/MSD samples for volatile organic parameters shall be collected as close to the location of the investigative sample as possible.

3. For aqueous samples for non-volatile organic parameters, alternately fill the investigative sample and MS/MSD sample containers by thirds until all three sets of containers are filled. If a temporary transfer container is being used for aqueous sample collection, agitate the sample between filling each third, at a minimum, to help keep the sample homogenized. Collect MS/MSD samples one parameter at a time. MS/MSD sample containers for volatile organic parameters should be filled completely; i.e., not in thirds, and collected immediately after the investigative sample. Temporary transfer containers shall not be used when collecting volatile organic parameter samples.

4. Label MS/MSD samples, as such, when submitted to the analytical laboratory.

5. After sample collection, seal the containers properly and in ice within 15 minutes place upright in an iced cooler, as specified by ENV-TI-05.80.02, Sample Labeling and Custody, and ENV-TI-05.80.06, Handling and Shipping of Samples.

6.5 Matrix Spike/Matrix Spike Duplicate (MS/MSD) Samples (continued)

6. Ship the MS/MSD samples with the associated investigative samples to the analytical laboratory, as specified by ENV-TI-05.80.06, Handling and Shipping of Samples.

7. MS/MSD samples are to be analyzed for the parameters identified in the QAPP and facility-specific SAP, or other planning documents.

6.6 Filter Blanks

A. Filter blanks are samples of laboratory-supplied DI water passed through in-line filters used in the collection of dissolved metals, or other analytes. The minimum frequency for filter blank collection is one per event, per sample team, when dissolved parameter samples are collected. If dissolved parameter samples are collected, a filter blank is to be collected as follows.

   1. Connect a new, clean 0.45-micron in-line filter to new, clean sample tubing.

   2. Using a peristaltic pump, submerge the inlet tube into a container of laboratory-supplied DI water.

   3. Turn on the pump and purge the in-line filter by pumping a minimum of 500 mL, but no more than 750 mL, of laboratory-supplied DI water through the filter.

   4. Fill the appropriate sample containers.

   5. Label the filter blank, as such, when submitted to the analytical laboratory.

   6. After sample collection, properly seal the containers and place upright in an iced cooler within 15 minutes of sample collection, as specified by ENV-TI-05.80.02, Sample Labeling and Custody, and ENV-TI-05.80.06, Handling and Shipping of Samples.

   7. Ship the filter blank samples with the associated investigative samples to the analytical laboratory as specified by ENV-TI-05.80.06, Handling and Shipping of Samples.

B. Filter blank samples are to be analyzed for the dissolved parameters identified in the QAPP and facility-specific SAP, groundwater monitoring plan, or other project record documents.

6.7 Tubing Blanks

A. Tubing blanks are samples of laboratory supplied DI water passed through sample tubing used in the collection of other samples during the sampling event (investigatory or QC samples). The minimum frequency for tubing blank collection is one per event, per sample team, when non-certified clean or non-dedicated tubing is used for sample collection or when dedicated tubing from the monitoring well is replaced. Tubing blanks are to be collected as follows.

1. Using a peristaltic pump, submerge the inlet of the new, clean tubing into a container of laboratory supplied DI water.
2. Turn on the pump and purge the tubing by pumping 500 mL of laboratory supplied DI water through the tubing.
3. After 500 mL of laboratory supplied DI water has passed through the tubing, fill the appropriate sample container(s).
4. Label the tubing blank, as such, when submitting to the analytical laboratory.
5. After sample collection, properly seal the containers and place upright in an iced cooler within 15 minutes of sample collection, as specified by ENV-TI-05.80.02, Sample Labeling and Custody, and ENV-TI-05.80.06, Handling and Shipping of Samples.
6. Ship the tubing blank samples with the associated investigative samples to the analytical laboratory as specified by ENV-TI-05.80.06, Handling and Shipping of Samples.

6.8 Other QC Sample Types

Section 6.8 describes additional types of QC samples that may be collected. Refer to the sample planning documents, such as facility-specific SAP and QAPP, for additional requirements and other QC sample types and collection frequencies.

A. Background samples, usually a grab sample, of the same type or matrix are collected from an area, water body, or site similar to the one being studied, but located in an area known or thought to be free from the effects of pollutants of concern that might originate from the facility being investigated. Background samples are to be collected as directed by the work plan, TVA Project Manager, or other investigative document, such as a facility-specific SAP and QAPP.

B. Trip blanks are a type of QC sample collected in association with samples scheduled for analysis of volatile organic compounds (VOCs). Refer to instructions in ENV-TI-05.80.43, Water Sampling for VOC Analysis, and ENV-TI-05.80.51, Soil Sampling for VOC Analysis.

6.8 Other QC Sample Types (continued)

C. PE samples may be submitted to the analytical laboratory with collected groundwater samples. For each parameter to be evaluated, a spiked PE sample and a blank PE sample will be prepared by a reputable vendor and shipped to each facility to coincide with groundwater sampling events. PE samples will be collected as directed by the TVA Project Manager and facility-specific SAP and labeled by the Field Team following the sample nomenclature specified by the facility-specific SAP and submitted to the laboratory for analysis with other groundwater samples.

D. Split samples are collected similarly to field duplicate samples of MS/MSD samples, depending on the number of parties, requiring twice as much volume as is normally collected. The material will be apportioned, after mixing, if appropriate, into two sets of split samples. Each party's sample containers will be filled by thirds, by parameter, with the exception of samples for analysis of VOCs, until all containers are full. Split samples are to be collected as directed by the TVA Project Manager and facility-specific SAP. Samples will be submitted for analyses per one of the following, depending on requirements specified by the work plan:

   1. Under the purview of TVA and a separate organization, such as a state environmental agency OR

   2. To two different laboratories, depending on requirement specified by the facility-specific SAP

E. Sample preservative blanks are collected when preservatives are stored in a single container; i.e., not single use vials, that will be used to preserve multiple samples in the field. Collect sample preservative blanks by adding DI water to sample containers, transporting them to the field, and adding preservative. They should be clearly identified as preservative blanks on labels and on custody sheets. Sample preservative blanks are to be collected as directed by the TVA Project Manager and as described in the work plan or other project control document; e.g., facility-specific SAP.

F. Organic-free water system blanks are collected by sampling raw source water when a portable organic-free water generating system is used in the field. Collect at a rate as described in the work plan or other project control document; e.g.; facility-specific SAP, and as directed by the TVA Project Manager.

G. Material blanks are collected from construction materials being used onsite in such a way as to have potential impact on constituent concentrations in investigative samples. Collect at a rate as described in the work plan, sample planning document, or other investigative document.

6.8 Other QC Sample Types (continued)

H. Automatic sampler blanks are collected by pumping analyte-free reagent water or DI water through automatic sampling systems. They are collected after field deployment or use of the system without changing tubing and after purging the system with the reagent water, as described in any operations TI for the equipment. Usually these are only collected when troubleshooting unexpected results or other special investigations.

I. Temperature blanks are containers of water of a size approximately equal to routine samples shipped with each cooler of samples which require demonstration of cooling to ice temperatures. They are utilized when the laboratory requests them or when the laboratory does not have capability to measure temperatures using non-contact techniques.

J. Wipe sample blanks are samples of the material and solvent used for collecting wipe samples. Handle, package, and transport the blank in the same manner as the investigatory wipe samples, with the exception that the blank is not exposed to actual contact with the sample medium. Collect at a rate as described in the sample planning document or other investigative document.

6.9 Sample Containers and Preservation

Field QC samples must be collected into containers suitable for the matrix and requested analyses and preserved commensurate with requested analytes per the guidance in ENV-TI-05.80.01, Planning Sampling Events, and ENV-TI-05.80.06, Handling and Shipping of Samples. Suitable quantities of field QC samples must be coordinated with the receiving laboratory per ENV-TI-05.80.01, Planning Sampling Events.

6.10 Field Records Management

Information associated with preparation and collection of field QC samples is recorded in field logbooks and/or electronic field data collection forms and Chain of Custody (COC) Records, similar to that of routine samples. Field logbooks and/or electronic field data collection forms and COC Records, associated with field sampling, are managed in accordance with ENV-TI-05.80.02, Sample Labeling and Custody, ENV-TI-05.80.03, Field Record Keeping, and TVA-SPP-31.01, Records Management.

7.0 RECORDS

Records generated in the process of performing the activities in this TI must be processed and maintained as stated in the Environmental Records Matrix, in accordance with the TVA Document Services Records Management procedures.

7.1 Quality Assurance Records

A. Field logbooks

B. COC records

7.2 Non-Quality Assurance Records

None

Attachment 1
(Page 1 of 2)

Definitions

Automatic sampler blanks - Samples collected by pumping constituent-free reagent water or deionized water through automatic sampling systems.

Background samples - Usually a grab sample of the same type or matrix collected from an area similar to the one being studied, but located in an area known or thought to be free from pollutants of concern.

Equipment rinsate blanks - Samples used to assess the effectiveness of field equipment decontamination procedures in preventing cross-contamination between samples and to assess the cleanliness of reusable dedicated and new disposable equipment.

Field blanks - Samples used to assess the potential for cross-contamination during the sampling process due to ambient conditions and to validate the cleanliness of sample containers.

Field duplicate samples - Samples used to assess the reproducibility of laboratory analytical results.

Filter blanks - Samples of water passed through filters used in certain sampling activities.

Material blanks - Samples collected from construction materials being used onsite which could have potential impact on constituent concentrations in investigative samples.

Matrix spike/matrix spike duplicate (MS/MSD) - Investigative samples (usually for organic analysis) to which known amounts of compounds are added in the laboratory before extraction and analysis. The recoveries for spiked compounds can be used to assess how well the method used for analysis recovers target compounds in the site-specific sample matrices.

Quality control (QC) samples - Those samples collected during field studies for various purposes, among which are to isolate site effects, to define background conditions, to evaluate field or laboratory variability, and to identify sources of interferences.

Organic-free water system blanks - Collected by sampling raw source water when a portable organic-free water generating system is used in the field.

Sample preservative blanks - Collected by adding deionized water to sample containers, transporting them to the field, and adding preservative.

Attachment 1
(Page 2 of 2)

Definitions

Split samples - Collected by initially collecting twice as much volume as is normally collected and then dividing between two containers.

Temperature blanks - Containers of water of a size approximately equal to routine samples that are shipped with each cooler of samples to demonstrate cooling to ice temperatures.

Trip blanks - Samples collected in association with samples scheduled for analysis of volatile organic compounds.

Tubing blanks - Samples collected to assess the cleanliness of sample tubing.

Wipe sample blanks - Samples of the material and solvent used for collecting wipe samples.

Environmental Operations

Technical Instruction

ENV-TI-05.80.05

FIELD SAMPLING EQUIPMENT CLEANING AND DECONTAMINATION

Revision 0000

Level of Use: Reference Use

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Revision Log

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0000	03/31/17	All	Initial Issue

Table of Contents

1.0 PURPOSE

This Technical Instruction (TI) describes the methods to be used when cleaning and decontaminating sampling equipment that has the potential to contact investigated media, including soil, groundwater, surface water, sediment, and other media. Cleaning and decontamination are conducted to remove contaminants from sampling equipment to concentrations that do not impact study objectives.

2.0 SCOPE

A. This TI applies to TVA field sampling personnel and TVA contractors who clean and/or decontaminate sampling equipment used for collecting samples, such as soil, sediment, water, and wastes, for various regulatory and operational purposes.

B. This TI was developed under the general guidelines of the Environmental Protection Agency (EPA) Field Equipment Cleaning and Decontamination and American Society for Testing and Materials (ASTM) Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites.

Review Cadence: This TI will be reviewed every four years with the review documented in the Revision Log.

3.0 PRECAUTIONS/LIMITATIONS

3.1 Precautions

None

3.2 Limitations

None

4.0 REFERENCES

4.1 Performance References

A. ASTM, D1193-06 (2011), Standard Specification for Reagent Water

B. ASTM, D5088-90, Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites

C. ENV-TI-05.80.01, Planning Sampling Events

D. ENV-TI-05.80.03, Field Record Keeping

E. EPA, Region 4, SESDPROC-205, Field Equipment Cleaning and Decontamination

F. EPA, Region 4, SESDPROC-206, Field Equipment Cleaning and Decontamination at the Field Equipment Center

G. TVA-SPP-18.005, Plan Jobs Safely

4.2 Developmental References

None

4.3 Commitments

None

5.0 PREREQUISITE ACTIONS

None

6.0 PERFORMANCE

6.1 General Considerations

A. Field personnel performing decontamination activities are required to be familiar with the procedures provided in this TI and any facility-specific Sampling and Analysis Plan (SAP) and Quality Assurance Plan (QAP), as well as standard industry practices.

B. Potential hazards associated with decontamination activities are to be thoroughly evaluated prior to conducting field activities. Prior to performing decontamination activities, procedures to ensure safety will be incorporated according to the TVA Standard Programs and Processes (SPP), TVA-SPP-18.005, Plan Jobs Safely, which provides information on using job safety analyses (JSAs) and pre-job briefings (PJB).

C. Sampling personnel are to wear powder-free latex or nitrile gloves while decontaminating sampling equipment for protection of personnel and to avoid equipment contamination.

D. Safety glasses with splash shields or goggles, gloves, and safety boots are to be worn during decontamination operations. An acid-resistant apron and acid-resistant gloves are to be worn during acid rinsing. A face shield and hearing protection are required when operating a pressure washer or steam cleaner.

E. Organic-free water, reagent water, isopropanol, and other purchased reagents must have lot numbers recorded in the field logbook or documented in other records, in accordance with ENV-TI-05.80.03, Field Record Keeping. Where appropriate, certificates of analysis for certain trace-level reagents shall be maintained in project files. High-purity water, including distilled water, deionized (DI) water, and reagent water may be produced in-house through the use of appropriate purification/filtration systems, or purchased for cleaning and decontamination activities.

Step 6.1E.1 Applies to CCR Only

1. DI water, used for the preparation of various types of blanks, must be obtained from the laboratory that will be receiving project samples for analysis.

F. High-purity water and reagents must be stored in clean containers that can be closed prior to use, and which are compatible with the materials stored therein. Water, soap solutions, and reagents may be applied from dedicated and properly labeled squeeze bottles.

G. See Attachment 1, Definitions.

6.2 Pre-Field Preparation

Prior to leaving for the collection site, the Field Team Lead is to ensure that the following activities have been completed:

A. Refer to the sampling diagram, chart, or plan to identify appropriate decontamination needed for the sampling event. Refer to ENV-TI-05.80.01, Planning Sampling Events.

B. Review JSA, current revision of this TI, and any applicable sample planning documents; e.g., a facility-specific SAP, QAP. Conduct a PJB. Document the review of project record documents and the PJB.

C. Obtain an adequate supply of equipment, solvents, soap, and water (both potable and high-purity) necessary for completing decontamination for the planned sampling activities at the site. See Attachment 2, Recommended Field Equipment Cleaning and Decontamination Materials Checklist for a recommended checklist of decontamination supplies and equipment. Attachment 2 is not intended to be an all-inclusive list and is provided only as an example.

D. Obtain appropriate personal protective equipment (PPE) for handling the cleaning and decontamination solutions that will be utilized. Obtain appropriate containment vessels for cleaning and decontamination wastes.

6.3 Equipment Cleaning and Decontamination

A. This section provides decontamination instructions for reusable manual sampling equipment, heavy equipment, and other items used for sampling, testing, or measuring, unless the equipment is prepackaged, certified clean, and sealed by a manufacturer. If the equipment or disposable sampling equipment is not certified clean, decontamination is required prior to use.

B. It is important to note that all decontamination activities must be fully documented in the site field logbook. Electronic means of recording these actions may be used.

6.3.1 Decontamination of Manual Sampling Equipment

A. This section is applicable to all equipment prior to initial use, unless using certified clean prepackaged environmental sampling equipment, or that have been utilized to collect sample media for analytical purposes. Site-specific project control documents; e.g., facility-specific SAP, QAP, may specify modifications to these procedures and are to be followed when applicable.

6.3.1 Decontamination of Manual Sampling Equipment (continued)

NOTE

No acids or organic solvents are used to decontaminate electrical or electronic instrumentation unless specified by the manufacturer.

1. For decontamination in the field, locate a decontamination area away from, and preferably downwind, from sampling areas. Place tubs and/or buckets and rinse bottles in their order of use in the decontamination area. Plastic sheeting, or other means to prevent contamination materials from contacting the ground, may be placed beneath the tubs and buckets. Acids and organic solvents should only be used during laboratory decontamination, and not during field decontamination. For decontamination in the laboratory, ensure laboratory space is clean and that ample counter space is available.

2. Prepare an ample volume of decontamination solution containing soap, non-phosphate detergent, and potable water. Record the source of the potable water in the field logbook, data or work sheets, or other appropriate field notebook, in accordance with ENV-TI-05.80.03, Field Record Keeping. Electronic means may be used to record field documentation.

   Prepare other decontamination solutions as needed, such as 10 percent nitric acid or isopropanol, depending on the media being sampled and analytes of concern.

3. Physically remove visible material from the sampling equipment to the extent practical. If this material appears to be impacted/contaminated, based on visual observation or other credible indication, collect and manage this material in accordance with Section 6.4.

4. Immerse, to the extent practicable per manufacturer’s instructions, the equipment in the soap solution and scrub the equipment thoroughly with a stiff brush until visible residual material is removed and the equipment is visibly clean. Circulate soap solution through equipment that cannot be disassembled. Refer to ASTM procedures in Section 4.0.

   Alternatively, use steam or high-pressure water instead of brushing to clean and decontaminate the equipment. Do not use steam on non-metal materials.

5. Rinse the equipment thoroughly with potable water, if practical.

6. Depending on the analytes of concern, rinse with the following solutions:

6.3.1 Decontamination of Manual Sampling Equipment (continued)

a. For organics analyses, rinse the equipment with organic desorbing agent (isopropanol). Then, rinse the equipment thoroughly with potable water, followed by a final rinse with organic-free water. Proceed to Step 6.3.1A.10.

b. For perfluorinated compounds analyses, clean equipment to be used for sample collection in accordance with instructions from EPA procedures in Section 4.0.

c. For chlorine measurements, rinse with a 10 percent nitric acid solution followed by another rinse with potable water. This is normally done in a laboratory.

d. For reusable composite sample containers, decontaminate in the laboratory by rinsing with hot potable water followed by a 10 percent nitric acid rinse and another potable water rinse.

7. Triple rinse the equipment thoroughly with high-purity water (DI or reagent-grade) water.

Step 6.3.1A.8 Applies to CCR Only

8. Triple rinse the equipment thoroughly with high-purity (laboratory-supplied DI or reagent-grade) water.

9. To the extent practicable, allow the equipment to air dry in a clean area. When trace organics are to be measured, place them to dry on a foil-covered surface. Equipment does not need to be completely dry before reuse. Under certain weather conditions, complete air drying is not possible.

10. Change the initial decontamination solution daily or between sites at a minimum. Change more frequently, as needed.

Step 6.3.1A.11 Applies to CCR Only

11. After decontamination, handle decontaminated equipment only when wearing clean, nitrile gloves to prevent re-contamination.

6.3.1 Decontamination of Manual Sampling Equipment (continued)

12. After decontamination, handle decontaminated equipment only when wearing clean gloves to prevent re-contamination. If practical, move cleaned equipment away, preferably upwind, from the decontamination area to prevent re-contamination. If decontaminated equipment will not be used immediately, wrap in aluminum foil, if used for organics only, or seal in a plastic bag for storage, and record the date of decontamination on a label or tape affixed to the surface of the foil or bag.

13. For operations involving parameters, such as oxygen demand, nutrients, and certain inorganic compounds, thoroughly rinse the sampling equipment, such as buckets, dunkers, and dredges, with the sample water between sampling locations.

Step 6.3.1A.14 Applies to CCR Only

14. In addition to information in Step 6.3.1A.13, a full decontamination is to be performed.

15. Collect decontamination solvents in a separate container from water and soap solutions. Properly containerize, store, and dispose of decontamination solutions, in accordance with Section 6.4.

16. Record decontamination activities, including date, time, and reagents used, in field logbook, on data sheets, or other appropriate field notebook. Record the lot number of chemicals used to prepare decontamination solutions, and the source of DI and potable water in the field logbook. Refer to ENV-TI-05.80.03, Field Record Keeping.

Step 6.3.1A.17 Applied to CCR Only

17. Record the lot number of chemicals, including soap/detergent and water used to prepare decontamination solutions, and the source of DI and potable water in the field logbook.

6.3.2 Decontamination of Downhole Drilling and Other Heavy Equipment

A. Any portion of a drill rig, backhoe, etc. that comes in contact with the sample matrix is to be decontaminated before beginning work on a new borehole and between boreholes, as described in this section. This section applies to field-cleaning augers, drill stems, rods, tools, and associated equipment. These procedures do not apply to well casings, well screens, or split-spoon samplers used to obtain samples for chemical analysis, which should be decontaminated as described in ENV-TI-PI, Monitoring Well and Piezometer Installation.

1. Locate a decontamination area away from, and preferably downwind of, sampling areas. Establish an area or pad for decontamination that will meet the program and site-specific requirements for collection of decontamination fluids.

2. Conduct gross decontamination, such as removing general mud from large equipment, prior to demobilization from the site. If contaminated material is suspected, as determined by visual observations, instrument readings, or other means, collect material in an appropriate container. Otherwise, return the material to the area where it originated.

3. Place the heavy equipment on the decontamination pad in the decontamination area. If wash water is to be collected, ensure that the collection mechanism functions properly and that the decontamination pad has no leaks.

4. Physically remove visible material from the sampling equipment to the extent practical. If this material appears to be impacted/contaminated, based on visual observation, instrument readings, or other means, collect and manage this material, in accordance with Section 6.4.

5. Pressure wash parts of the heavy machinery that contact the soil, sediment, or surface material, such as tires, bulldozer bucket, augers, and the back of the drill rig. Wash with potable water and non-phosphate detergent, using a brush, if necessary, to remove visible particulate matter and surface films.

6. For any portion of the heavy equipment that comes into contact with the sampling media, decontaminate by following Steps 6.3.1A.3 through 6.3.1A.6.d.

7. Decontaminate equipment between sampling sites.

6.3.2 Decontamination of Downhole Drilling and Other Heavy Equipment (continued)

8. Immerse, to the extent practical per manufacturer’s instructions, the equipment in the soap solution and scrub the equipment thoroughly with a stiff brush until visible residual material is removed and the equipment is visibly clean. Circulate soap solution through equipment that cannot be disassembled, as specified by ASTM, D5088-90, Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites.

9. Steam cleaning, high-pressure hot water and detergent, may be necessary to remove material that is difficult to remove with a brush. Do not use steam on non-metal materials. Drilling equipment that is steam cleaned, is to be placed on racks or saw horses at least two feet above the floor of the decontamination pad.

10. Drilling equipment that is hollow or has holes to transmit water is to be thoroughly cleaned, inside and out, with potable water.

11. If drilling tools and equipment are to be used during sample collection or have potential to contact samples, perform a thorough DI rinse of the drilling tools and equipment.

12. Remove the equipment from the decontamination pad and cover with clean, unused plastic. The plastic is to be secured to ensure it stays in place while decontaminated equipment is stored/staged prior to use. Performance of decontamination activities are to be documented in the field logbook.

13. Containerize fluids and solids, if appropriate, according to Section 6.4.

6.3.3 Cleaning and Decontamination of Miscellaneous Items

A. Multiparameter Sondes: Wipe multiparameter sonde (such as Hydrolab®) with a clean, damp cloth, and rinse probes on the instrument with DI water. Do not rinse sensors with alcohols or acid unless specified by the manufacturer. If needed, soak sensors in soap solution to remove biological, oil, or sediment buildup, and then rinse with DI water. For specific details on different sensors, follow manufacturers’ instructions. In the field, when sampling waters at multiple sites, thoroughly rinse sonde with sample before collecting measurements.

B. Automatic Samplers: In a laboratory, clean automatic sampler headers by disassembling them, scrubbing with a small soft brush, rinsing with hot potable water, and then thoroughly rinsing with DI water. Allow to dry, then reassemble, wrap in aluminum foil, and seal in a plastic bag. Replace tubing for automatic samplers, in accordance with manufacturer’s instructions or in accordance with the work planning documents, facility-specific SAP, QAP, etc.

6.3.3 Cleaning and Decontamination of Miscellaneous Items (continued)

C. Pumps, Tubing, and Check Valves: In the laboratory, remove hose, if attached, and ball check valve. Using a dry brush or scrub pad, scrub exterior of the pump and the electrical cord. Run soap and potable water solution through the pump, then place pump in potable water and flush to clean inside of pump. Follow this with a DI, or other high-purity, water rinse through the pump to flush out potable water and any soap residue. Allow to completely air dry. Using a brush, scrub all components of the ball check valve with soap and potable water, rinse with high-purity water, and allow to completely air dry. Reinstall the check valve on the pump, then place pump in clean plastic bag. Replace Silastic® pump tubing after each study. Do not reuse or decontaminate. In the field, decontaminate pumps between sites by washing exterior with soap and water solution and rinsing with high-purity water.

D. Replace dedicated pump tubing and pump bladders, in accordance with frequency specified in ENV-TI-05.80.21, Monitoring Well Inspection and Maintenance, or as specified in the facility-specific SAP, to minimize the impact of tubing material degradation and bacterial growth to groundwater samples.

E. Portable Tanks for Potable Water: Clean interior and exterior of tanks with soap and potable water, rinse with potable water, and allow to completely drain and allow to air dry, if possible.

F. Ice Chests: Wash the interior and exterior of ice chests or other reusable shipping containers with soap, rinse with potable water, and air dry before storage. Clean severely contaminated containers as thoroughly as possible, render them unusable, and dispose of them properly.

G. Vehicles: If warranted, based on site rules or the type and degree of contamination, wash exterior of vehicles that become contaminated during the course of field investigation.

6.4 Investigation-Derived Waste

Investigation-derived wastes such as PPE, waste media, and cleaning/decontamination fluids are to be managed in accordance with Table 1, Investigation-Derived Waste Steam. When possible, coordinate with the appropriate facility personnel to arrange for disposal of investigation-derived waste based on results of analytical data or in accordance with the facility specific waste management plan.

6.4 Investigation-Derived Waste (continued)

Investigation-Derived Waste Stream	Disposition Pathway
General refuse (such as paper, plastic bags, and cardboard)	Dispose as municipal trash or recycle as appropriate.
PPE (such as disposable gloves and Tyvek®)	Dispose as municipal trash for routine activities. If it is likely that PPE is contaminated with hazardous materials, containerize PPE. Pending analytical results of associated samples, dispose of appropriately.
Non-hazardous cleaning and decontamination soaps and rinse waters	Dispose of non-hazardous rinse waters from equipment decontamination in sanitary drains or release onto the ground without recovery. Dispose of non-hazardous cleaning solutions and soaps in sanitary drains
Hazardous decontamination fluids, solids, or wastewaters	Containerize in appropriate containers dependent on user's knowledge of the decontamination fluids, media solids, and wastewaters and dispose appropriately based on analytical results.

Table 1, Investigation-Derived Waste Steam

6.5 Field Logbooks

Field logbooks or data sheets (electronic forms may be used) for recording daily activities, including date, time, sequence of washing and rinsing, and reagents used, are to be maintained by the Field Team Lead or designee. Information is to be entered into the field logbook by the appropriate field team member using indelible ink. In addition to the minimum requirements discussed in ENV-TI-05.80.03, Field Record Keeping, field logbooks are to document sampling characteristics specific to this TI.

7.0 POST PERFORMANCE ACTIVITY

None

8.0 RECORDS

Records generated in the process of performing the activities in this TI must be processed and maintained as stated in the Environmental Records Matrix, in accordance with the TVA Document Services Records Management procedures.

8.1 Quality Assurance Records

- Field logbooks, notebooks, and data sheets

8.2 Non-Quality Assurance Records

None

Attachment 1
(Page 1 of 1)

Definitions

De-ionized (DI) water - Tap water that has been treated by passing through a standard de-ionizing resin column. At a minimum, the finished water should contain no detectable heavy metals or other inorganic compounds (above analytical detection limits) as defined by a standard inductively coupled Argon Plasma Spectrophotometer (ICP) or equivalent scan. Organic-free water may be substituted for DI water.

Distilled water - Water that is boiled and the steam captured and condensed into a clean container. Distillation removes many impurities found in tap water.

Organic-free water - Tap water that has been treated with activated carbon and de-ionizing units. At a minimum, the finished water must meet the analytical criteria of DI water and is to contain no detectable pesticides, volatile organic compounds, herbicides, or extractable organic compounds.

Potable water - Tap or other water safe enough to be consumed by humans or used with low risk of immediate or long-term harm.

Nitric acid solution - Made from reagent-grade nitric acid (10%) and DI water (90%). Nitric acid solution used to clean equipment cannot be reused.

Reagent water - Water that is interference free and conforms to the performance specifications of American Society for Testing and Materials (ASTM) Type 1-4 water (ASTM D1193).

Soap - Standard brand of phosphate-free laboratory detergent such as Luminox® or Liqui-Nox.

Solvents - Pesticide-grade isopropanol used for specific application. Pesticide-grade acetone or methanol is also acceptable. If pesticide-grade acetone is used, the detection of acetone in samples collected with acetone rinsed equipment is considered suspect. Pesticide-grade methanol is much more hazardous than acetone or isopropanol, and therefore its use is discouraged. Solvents used to clean equipment cannot be reused.

Attachment 2
(Page 1 of 1)

Recommended Field Equipment Cleaning and Decontamination Materials Checklist

Item Description	Check
Health and Safety	
Non-powder latex or nitrile gloves	
Hard hat and safety boots	
Hearing protection	
Field first-aid kit	
Safety glasses with splash shields or goggles for most decontamination activities	
Face shield (for use when pressure washing)	
Eyewash	
Acid-resistant apron and gloves for acid rinsing	
Barricades, cones, flashing lights, signs	
Respirator and cartridges, as necessary	
Saranex™/Tyvek® suits and booties, as necessary	
Paperwork	
JSA and PJB	
Project work control documents	
Field logbook or data sheets or field notebooks	
Equipment	
Soap (non-phosphate detergent, such as Luminox® or Liqui-Nox)	
Isopropanol or other solvents	
Nitric acid solution (10%)	
Potable water, DI water, organic-free water, or reagent water, as needed	
Buckets or washtubs	
Spray bottles	
Drums (with labels)	
Plastic sheeting	
Brushes	
Pressure washer, as needed	
Aluminum foil	
Plastic resealable bags	

Environmental Operations

Technical Instruction

ENV-TI-05.80.06

Handling and Shipping of Samples

Revision 0000

Level of Use: Reference Use

Effective Date: 03-31-2017

Responsible Organization: Environmental Compliance and Operations

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Revision Log

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0000	03/31/17	All	Initial Issue

Table of Contents

Table of Contents (continued)

1.0 PURPOSE

This Technical Instruction (TI) provides the technical requirements for the handling and shipping of samples to ensure that samples taken are representative of the medium being sampled; to ensure proper handling and preservation techniques; to ensure proper identification of samples and proper documentation of their collection; to maintain sample Chain of Custody (COC); and to protect collected samples by properly packing and transporting them to designated laboratories for analysis and testing.

2.0 SCOPE

A. This TI applies to TVA field sampling personnel and TVA contractors who collect, handle, and ship samples for analysis for various regulatory and operational purposes.

B. This TI applies to samples of all types, such as surface water, groundwater, waste water, solid waste, soil, sediment, and waste. It covers operations, including packaging and shipping samples and associated record keeping and is based on guidance from Environmental Protection Agency (EPA) Region 4 and Department of Transportation (DOT).

Review Cadence: This TI will be reviewed every four years with the review documented in the Revision Log.

3.0 PRECAUTIONS/LIMITATIONS

3.1 Precautions

None

3.2 Limitations

None

4.0 REFERENCES

4.1 Performance References

A. ENV-TI-05.80.02, Sample Labeling and Custody

B. ENV-TI-05.80.03, Field Record Keeping

C. ENV-TI-05.80.04, Field Sampling Quality Control

D. International Air Transport Association (IATA), Dangerous Goods Regulations, 49th Edition, Montreal, 2008.

E. International Civil Aviation Organization (ICAO), The ICAO Technical Instructions on the Safe Transport of Dangerous Goods by Air, 2007 - 2008 Edition.

F. International Maritime Organization, International Maritime Dangerous Goods (IMDG) Code, 2006 Edition.

G. Office of the Federal Register, National Archives and Records Administration, 49 CFR Parts 171-179, U.S. Government Printing Office, Washington, DC, 2006.

H. TVA-SPP-18.005, Plan Jobs Safely

4.2 Developmental References

A. DOT, Letter from Edward T. Mazzullo, Director, Office of Hazardous Materials Standards, to Henry L. Longest II, Acting Assistant Administrator, U.S. EPA, Ref No. 02-0093

B. EPA, Final Regulation Package for Compliance with DOT Regulations in the Shipment of Environmental Laboratory Samples, Memo from David Weitzman, Work Group Chairman, Office of Occupational Health and Safety (PM-273), April 13, 1981

C. EPA, Region 4, Analytical Support Branch Laboratory Operations and Quality Assurance Manual (ASBLOQAM).

D. EPA, Region 4, SESDPROC-11, Field Sampling Quality Control

E. EPA, Region 4, SESDPROC-209, Packing, Marking, Labeling, and Shipping of Environmental and Waste Samples

F. EPA, Region 4, SESDPROC-005, Sample and Evidence Management

4.3 Commitments

None

5.0 PREREQUISITE ACTIONS

None

6.0 PERFORMANCE

6.1 General Considerations

The potential hazards associated with sample handling, packing, and shipping are to be thoroughly evaluated. During sample handling and packing activities, procedures to ensure safety will be incorporated according to the TVA Standard Programs and Processes (SPP) TVA-SPP-18.005, Plan Jobs Safely, which provides information on using job safety analyses (JSAs) and pre-job briefings (PJBs).

Refer to Attachment 1, Definitions.

6.2 Pre-Field Preparation

The following steps are conducted by the Field Team Lead prior to initiating sampling efforts:

A. Verify that sample types, number of samples, including field quality control samples, preservatives, and the required analyses are known.

B. Obtain packing and shipping materials such as those listed in the example checklist provided in Attachment 2, Recommended Packing and Shipping Equipment and Material Checklist. The items in the example checklist are not intended to be all-inclusive; the preparation of an event-specific checklist of equipment and materials is highly recommended. Refer to the field logbook and copies of the sample planning documents, facility-specific Sampling and Analysis Plan (SAP) and Quality Assurance Plan (QAP), as needed.

6.2 Pre-Field Preparation (continued)

C. If necessary, verify that a suitable, secure cold storage unit is available for sample storage if the collected samples are not able to be shipped the same day as collected and multiple-day storage is required. To be considered suitable, verify the following minimum requirements for a cold storage unit.

1. The unit is lockable or located in an access-controlled area.

2. Documented control of access, in the form of a sign-in/sign-out sheet, is posted on the outside of the unit to document the date, time, and persons accessing the unit and the addition, and removal of any samples or other materials.

3. The unit contains a NIST-traceable thermometer to monitor the internal temperature of the unit.

Step 6.2C.4 Applies to CCR Only

4. The NIST thermometer is to be properly calibrated and labeled with calibration sticker displaying the date of last calibration and calibration due date.

5. The unit is capable of maintaining sample temperature between zero and six degrees Celsius. The temperature of the unit is to be observed and documented on the sign-in/sign-out sheet when samples are added to, or removed from the unit. If it is necessary to store the samples for multiple days, the temperature of the unit will be observed and documented daily, at a minimum.

D. If short-term; e.g., overnight, storage of samples is required during the performance of a sampling event prior to sample shipment, storage of samples in custody sealed sample coolers with set ice is acceptable if the following conditions are met:

1. The sample cooler is custody sealed, in accordance with ENV-TI-0580.02, Sample Labeling and Custody **AND**

2. The sample cooler is located in a temperature-controlled environment to prevent excessive ice melt fro occurring **AND**

3. The amount of ice present in the sample cooler is checked, and replenished, as necessary, a minimum of once per day **AND**

4. The performance of inspecting the amount of ice in the sample cooler and replenishment of ice, as needed, is documented in the field logbook, in accordance with ENV-TI-05.80.03 Field Record Keeping.

6.2 Pre-Field Preparation (continued)

E. Verify methods to be used to transport samples, such as the contractor's courier or commercial driver. Identify the telephone numbers, locations, and any special requirements of couriers that are used.

F. Prepare COC records and sample labels in accordance with ENV-TI-05.80.02, Sample Labeling and Custody

G. Prepare DOT paperwork in advance, where practical. A trained transportation subject-matter expert shall be consulted to complete shipping papers for hazardous materials.

6.3 Sample Handling

Proper sample handling following sample collection is important to prevent cross-contamination of the samples. Proper handling helps with ensuring samples meet preservation and hold time requirements stated in the analytical method specified in sample planning documents, the facility-specific SAP and QAP, etc. Proper handling of samples helps to ensure the samples remain representative of the sampled media.

6.3.1 Cross-Contamination

If possible, potentially low concentration sources are to be sampled by different teams than those collecting potentially high concentration sources, with the collected samples being segregated prior to and during shipping. When it is not practical to use multiple sampling teams, lower concentration samples are to be sampled first. Samples known to be highly contaminated should never be shipped in the same cooler as samples expected to have little or no contamination. Liners are always to be used for sample shipping coolers and ice chests.

6.3.2 Sample Preservation

A. Preserve samples in accordance with the requirements of the analytical method, as stated in the SAP and QAP, if applicable. Sample preservation is achieved with a chemical (acid or base) preservative and/or chilling the samples to a temperature range of zero to six degrees Celsius (for samples collected in Kentucky, the temperature range is zero to four degrees Celsius). Refer to Attachment 3, Preservatives Information, for more information on preservatives.

B. Certain samples should not be chemically preserved in the field when from a hazardous waste site that are thought to be highly contaminated with reactive materials or samples with extremely high or low pH which may generate dangerous gases when mixed with a preservative.

6.3.2 Sample Preservation (continued)

C. Chill samples, requiring temperature preservation, to the appropriate temperature range of zero to six (zero to four for Kentucky) degrees Celsius. Maintain them at this temperature range through sample transport and receipt at the laboratory, as follows:

1. Place samples (with individual container inside re-sealable plastic bags), requiring temperature preservation, immediately on ice in a cooler to facilitate thermal equilibration and maintain within the appropriate temperature range of zero to six degrees Celsius. Place ice in a sealable plastic bag(s), or some equivalent container, to prevent cross-contamination from melting ice. Check the cooler regularly, and drain water and replenish ice, as needed. Document the replenishment of ice in the field notebook.

2. If the samples are to be held overnight prior to shipping, the samples may be placed in a suitable cold storage unit, as described in Section 6.2.

WARNING

If a cooler containing dry ice is used, do not place head near the inside of the cooler because the sublimation of dry ice can cause asphyxiation.

3. Maintain all samples, requiring frozen preservation, at a temperature of less than or equal to minus 10°C with the use of dry ice or in a freezer. Don protective (insulated) gloves, such as leather or thermal cloth before handling dry ice or placing hands inside a cooler containing dry ice. Place samples in a dry cooler containing sufficient amount of dry ice or in an onsite freezer. Maintain samples on dry ice or in freezer until preparations are made for packing the samples for shipment.

6.3.3 Sample Holding Times

In general, minimizing the time that elapses between the collection of a sample and its delivery to the analytical laboratory is preferable. Personnel involved with packaging and shipping samples must be aware of holding times. EPA documents usually include a maximum holding time associated with various analytes and methods of analysis. It is the responsibility of the Field Team Leader to be aware of short hold times and to ensure the samples are delivered to the laboratory in a timely manner.

6.4 Sample Packing and Shipping

Section 6.4 describes the procedures for packing and shipping of refrigerated and frozen samples. Attachment 2, Recommended Packing and Shipping Equipment and Material Checklist provides a recommended list of equipment and materials. Attachment 2 is not intended to be all-inclusive. The preparation of an event-specific checklist of equipment and materials is highly recommended.

6.4.1 Packing for Shipping Refrigerated Samples

Following sample collection, take care to minimize contamination during storage. The following provides the steps required for packing and sealing refrigerated samples for shipment:

A. Obtain collected samples in the laboratory-specified/provided containers and verify the completeness of the sample identification information on the label and the COC Record. Refer to ENV-TI-05.80.02, Sample Labeling and Custody. Verify that all samples and sample bottles recorded on the COC Record are accounted for and that the information on the sample labels and the COC Record are in agreement with the COC Record. Sample verification also includes, but is not limited to, verifying that custody seals on sample containers and/or bags, if present, are intact and have been initialed and dated, and verifying the lids of the sample containers are securely tightened to minimize the potential of leakage.

B. When packaging aqueous samples or using wet ice for temperature preservation, place a liner in the cooler.

C. Place each sample bottle in re-sealable plastic bags and then into the cooler. If applicable, place a temperature blank in the center of the cooler. Refer to ENV-TI-05.80.04, Field Sampling Quality Control.

D. Place ample amounts of wet ice contained in doubled re-sealable bags inside the lined sample cooler. As needed, place bubble wrap or other inert packing material around the liner in the sample cooler.

   1. For bulk water samples, such as those collected for toxicity testing in cubitainers, place loose ice around the sample when using local couriers (e.g., Sonic Delivery, Inc.). Write label information on cubitainer, using permanent marker, in case ice causes label to come off. This method of packing coolers does not apply to bulk water shipments using UPS or FedEx.

   2. For particulate matter sample media, reusable products; e.g., Blue Ice® may be used for temperature maintenance.

6.4.1 Packing for Shipping Refrigerated Samples (continued)

E. Seal the sample cooler liner with duct tape, cable ties, or by knotting the liner material. This is to ensure that if the contents were to spill that the liner would contain the spill.

F. Place a self-adhesive label or tape label on each cooler, indicting cooler number based on total number of coolers shipped each day; e.g., 4 of 8. Use a water-proof indelible ink pen to record the number on the label.

G. The person who has custody of the samples relinquishes the samples on the COC Record by signing his/her name and recording the date and time that the samples were relinquished.

H. Write the shipper's tracking number, such as courier and courier airbill number, on the COC Record when a commercial courier is used, if known at time cooler is sealed.

I. Place the original, completed COC Record in a large resealable plastic bag and tape the bag to the inside of the lid of the cooler. If multiple coolers are needed for a single COC Record, place a copy of the original COC Record inside a re-sealable plastic bag and tape the bag to the inside of the lid of each cooler that contains the samples identified on the COC Record.

NOTE

When packing multiple coolers, the time on the custody seal may not exactly match the time on the COC Record.

J. The individual who relinquished the samples in Step 6.4.1G is to sign and write the date and time on the custody seals for the sample coolers. The custody seal signature, dates, and times should match the relinquished signature, dates and times as they appear on the COC Record from Step 6.4.1G

K. Place tamper-evident custody seals or custody tape on two sides of the sample cooler, such that opening the cooler breaks the custody seal or custody tape. Tamper-evident custody seals or custody tape must be able to indicate that the seal has been disturbed, such as leave remnants of the seal or some type of ink residue on the surface when the seal is lifted, and must be able to remain adhered to the cooler surface, subject to normal handling during shipment.

NOTE

When shipping by UPS and FedEx, it may be prudent to cover the tamper-evident custody seals with clear tape to protect them from damage during shipping. It is strongly urged when shipping by UPS, FedEx, or a new courier that individual sample containers, bottles, jars, and bags also have custody seals to ensure custody is maintained, even if the seals on the shipping coolers are broken.

6.4.2 Sample Packing for Shipping Frozen Samples

In addition to the steps identified in Section 6.4.1, the following steps are required for packing and sealing frozen samples for shipment on dry ice:

A. Place inert material, such as bubble wrap and/or cardboard, in the bottom of the sample cooler.

B. Place samples requiring frozen preservation in the sample cooler on top of the inert material.

C. Place an additional piece of inert material on top of the samples to prevent the samples from contacting the dry ice.

CAUTION

Do not place more than one layer of dry ice in the cooler. The weight of the dry ice may cause container breakage.

D. Put on leather or insulating gloves and place one layer of dry ice, approximately two inches thick, on top of the second layer of inert material, covering as much surface area as possible.

6.4.2 Sample Packing for Shipping Frozen Samples (continued)

E. If using a commercial courier to transport the sample cooler with dry ice by domestic air freight, place a placard on the outside of the sample cooler, following the 49 Code of Federal Regulations (CFR) and International Air Transport Association (IATA) regulations presented below:

1. For non-medical, non-hazardous U.S. domestic air packages with less than or equal to 5.5 pounds (less than or equal to 2.5 kg) of dry ice, mark the outside of the cooler with one of the following and a description of the non-hazardous material, such as waste water:

    a. Less than or equal to 5.5 pounds dry ice **OR**

    b. Less than or equal to 5.5 pounds carbon dioxide, Solid

2. For non-medical U.S. domestic packages with greater than 5.5 pounds (greater than 2.5 kg) of dry ice, the following are required under 49 CFR and IATA.

    a. Hazardous materials shipping papers are completed.

    b. Package is properly marked as containing dry ice (or carbon dioxide, solid), UN1845, with a Class 9 Diamond label.

    c. Net weight of dry ice is indicated, in kilograms, on the shipping papers and is also marked on the outer package.

    d. Shipping paperwork is processed through UPS WorldShip 2008 version 10.0, or higher, CampusShip, or compliant software.

6.5 Shipping Procedures

A. If a courier other than UPS or FedEx is used for sample transport, a process for tracking sample delivery and receipt is to be used. This process is initiated by the Field Team Lead, or designee, prior to transfer of sealed sample coolers or containers to courier representatives for subsequent transport to the analytical laboratory. A record is to be retained by the Field Team Lead or designee with associated COC records to document the proper transfer of custody-sealed coolers/containers from the sample custodian or designee to the courier, and then from the courier to the analytical laboratory.

B. Samples are shipped as one of the following:

1. Non-hazardous material **OR**

2. Hazardous material or dangerous goods

6.5 Shipping Procedures (continued)

C. A trained transportation subject-matter expert shall be consulted to determing the proper shipping category of hazardous materials. Refer to Attachment 4, EPA Region 4 - Guidance on Shipment of Samples, for EPA guidance on shipping of samples and Attachment 5, TVA Sample Shipment Interpretation, for TVA's shipment guidance.

6.5.1 Samples Shipped as Non-Hazardous Material

[1] Ship samples as non-hazardous material unless the samples meet the established 49 CFR Hazardous Materials Regulations (HMR) criteria for a hazardous material or the IATA, ICAO Technical Instructions, and IMDG Code definition of dangerous goods. Refer to Section 6.4.2E.

[2] When preparing the sample cooler for shipment, remove old labels from the outside of the container prior to applying the new shipping labels and custody seals.

[3] When completing the paperwork for shipment, complete the standard non-hazardous shipping forms provided by the courier.

6.5.2 Samples Shipped as Dangerous Goods or Hazardous Material

A. IATA, IMDG, and 49 CFR HMR regulations govern the shipment of hazardous materials and dangerous goods. These regulations (49 CFR Parts 171 - 180 and the Dangerous Goods Regulations [DGR] for IATA and IMDG) describe proper marking, labeling, placarding, packaging, and shipping of hazardous materials.

1. IATA regulations apply strictly to domestic and international commercial air transportation.
2. IMDG regulations apply to the international transport of dangerous goods by waterway.
3. DOT regulations apply to domestic and international shipments originating in or imported to the U.S.

B. Determination and shipment of dangerous goods or hazardous materials are to only be made by trained and certified personnel.

6.6 Laboratory Receipt and Inspection

The TVA Project Manager, or designee, is to confirm that the contracted laboratory personnel are aware of the sample receipt requirements included in the project Technical Requirements Manual and/or the analytical laboratory contract. In the absence of these documents, laboratory sample receipt and inspection requirements include, but are not limited to, the following.

[1] Upon receipt, the contracted laboratory is to inspect all sample coolers for evidence of tampering, such as broken custody seals.

[2] In the event that custody seals are missing or broken, the laboratory is to report this condition to the designated TVA contact immediately.

[3] The laboratory is to record the condition of sample containers and accept the samples by signing the COC Record and recording the date and time in the appropriate location.

[4] For sample shipments that require temperature preservation, the laboratory is to measure and record the sample temperature, upon receipt, using the temperature blank or by direct, non-intrusive measurement of the sample(s).

[5] For samples that require chemical preservation, except for samples submitted of volatile organic analysis, the laboratory is to measure and record the pH of the sample upon receipt.

[6] The laboratory is to include the original COC Record and documented changes to the original COC Record as part of the final analytical report. This record is used to document sample custody transfer from the sampler to the laboratory and becomes a permanent addition to the files.

6.7 Field Logbook Documentation

Field logbooks recording daily sample handling and shipping activities, including sample verification and tracking information, are maintained by the Field Team Lead. Information is recorded into the field logbook by the appropriate field team member, using indelible ink. In addition to the minimum requirements discussed in ENV-TI-05.80.03, Field Record Keeping, the field logbooks are to document the following shipping activities:

A. Method of transportation

B. Courier tracking number

C. Material shipped (e.g., sample COC numbers) associated with each courier tracking number

D. Date shipped

7.0 POST PERFORMANCE ACTIVITY

None

8.0 RECORDS

Records generated in the process of performing the activities in this TI must be processed and maintained as stated in the Environmental Records Matrix, in accordance with the TVA Document Services Records Management procedures.

8.1 Quality Assurance Records

A. Chain of Custody forms

B. Field logbooks

C. Shipping records

8.2 Non-Quality Assurance Records

None

Attachment 1
(Page 1 of 1)

Definitions

Dangerous Goods - Articles or substances which are capable of posing a significant risk to health, safety, or to property when transported by air and which are classified according to the UN hazard classes.

Hazardous Material - A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. The term includes hazardous substances, hazardous wastes, marine pollutants, and elevated temperature materials. Quantities of certain dangerous goods may be transported as Small Quantity Exception or Limited Quantity Exception.

Attachment 2
(Page 1 of 1)

Recommended Packing and Shipping Equipment and Material Checklist

Item Description	Check
Health & Safety	
Nitrile or latex gloves	
Steel-toed boots	
Field first-aid kit	
Eyewash	
Safety glasses	
Leather or insulating gloves	
Respirator and cartridges, if necessary	
Saranex™/Tyvek® suits and booties, if necessary	
Paperwork	
JSA and PJB, as needed	
Project work control documents and sample planning documents	
Chain of Custory forms	
Field logbook	
Shipping forms and courier forms	
Shipping labels	
Packing and Shipping Supplies	
Packing tape	
Tamper-evident custody seals/tape	
Coolers	
Plastic bags for cooler liners	
Resealable plastic bags (gallon and pint sizes)	
Bubble wrap or cardboard	
Ice (wet and dry)	
Permanent indelible markers or pens	
Scale	
IATA Dangerous Goods Regulations Manual	

Attachment 3
(Page 1 of 1)

Preservatives Information

A. Ice - Sufficient ice must be placed in the shipping/transport container to ensure ice is still present when the samples are received at the lab.

B. HCl - Hydrochloric Acid used as a preservative must be present at concentrations less than or equal to 0.04 percent by weight (pH about 1.96 or greater) as specified in 40 CFR 136.3, Table II, footnote 3. The proper amount of HCl is added to the sample container at the laboratory prior to sampling.

C. H_2SO_4 - Sulfuric acid used as a preservative must be present at concentrations less than or equal to 0.35 percent by weight (pH about 1.15 or greater), as specified in 40 CFR 136.3, Table II, footnote 3. Approximately 5 mL of the laboratory-prepared preservative is added to the sample.

D. NaOH - Sodium hydroxide, used as a preservative, must be present at concentrations less than or equal to 0.080 percent by weight (pH about 12.30 or less), as specified in 40 CFR 136.3, Table II, footnote 3. Four tablets are added to the sample after collection.

E. HNO_3 - Nitric acid used as a preservative must be present at concentrations less than or equal to 0.15 percent by weight (pH about 1.62 or greater), as specified in 40 CFR 136.3, Table II, footnote 3. Approximately 5 mL of the laboratory prepared preservative is added to the sample.

F. Chromium VI buffer – A concentrated buffer is used to extend the holding time for hexavalent chromium samples from 24 hours to 28 days and uses constituents as allowed by EPA guidance found at: http://water.epa.gov/scitech/methods/ cwa/questions-cr6.cfm. The sample preservation buffer is prepared by carefully dissolving 330 g ammonium sulfate and 50 g sodium hydroxide in about 500 mL of deionized water. The solution is allowed to cool and 260 mL of 29 percent ammonium hydroxide is added and solution is diluted with deionized water to a final volume of 1 L. In house studies revealed that the equivalent of 1 percent of buffer volume is needed to preserve samples to attain the pH range (pH 9.3 to 9.7, 10 mL buffer for a 1 L sample) as specified in 40 CFR 136.3 Table II. Adding preservative to sample bottles prior to shipment to the field is recommended to minimize sampler contact with the buffer.

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EPA Region 4 - Guidance on Shipment of Samples

A. The Field Team Lead is responsible for determining if samples collected during a specific field investigation meet the definitions for dangerous goods. If a sample is collected of a material that is listed in the IATA, Section 4.2, Dangerous Goods List, then that sample must be identified, packaged, marked, labeled, and shipped according to the instructions given for that material. If the composition of the collected sample(s) is unknown and the Team Lead knows or suspects that it is a regulated material (dangerous goods), the sample may not be offered for air transport. If the composition and properties of the waste sample or highly contaminated soil, sediment, or water sample are unknown, or only partially known, the sample may not be offered for air transport.

B. In addition, the shipment of pre-preserved sample containers or bottles of preservatives, such as NaOH pellets or HCl, which are designated as dangerous goods by IATA is regulated. Shipment of nitric acid is strictly regulated. Consult the IATA Dangerous Goods Regulations for guidance. Dangerous goods can only be offered for air transport by personnel trained and certified by IATA in dangerous goods shipment.

C. The following unpreserved samples are not regulated in shipping under Final National Guidance Package for Compliance with Department of Transportation Regulations in the Shipment of Environmental Laboratory Samples and EPA’s Packing, Marking, Labeling, and Shipping of Environmental and Waste Samples.

    1. Drinking water

    2. Treated effluent

    3. Biological specimens

    4. Sediment

    5. Water treatment plant sludge / Publicly Owned Treatment Works (POTW) sludge

Attachment 4
(Page 2 of 2)

EPA Region 4 - Guidance on Shipment of Samples

D. In addition, the shipment of the following preserved samples is not regulated, provided the amount of preservative used does not exceed the amounts found in 40 CFR 136.3 or the EPA Analytical Support Branch Laboratory Operations and Quality Assurance Manual. This provision is also discussed in correspondence between DOT and EPA DOT Letter. It is the shippers' responsibility to ensure that proper amounts of preservative are used.

1. Drinking water
2. Ambient water
3. Treated effluent
4. Biological specimens
5. Sediment
6. Wastewater Treatment plant sludge
7. Water treatment plant sludge

E. Samples determined by the Field Team Lead to be in these categories are to be shipped using the following protocol, developed jointly between EPA, OSHA, and DOT. This procedure is documented in the Final National Guidance Package for Compliance with Department of Transportation Regulations in the Shipment of Environmental Laboratory Samples (DOT).

F. Untreated wastewater and sludge from POTWs are considered to be diagnostic specimens (not environmental laboratory samples). However, because they are not considered to be itiologic agents (infectious), they are not restricted and may be shipped as unregulated samples.

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TVA Sample Shipment Interpretation

As discussed in Attachment 2 by EPA Region 4 guidance, routine environmental samples with proper preservation may be shipped by air. Preservation, as described in Attachment 3, Preservatives Information, is allowed. In all other cases, knowledge of the Field Team Lead, sampling team, or from field team observations must be used to decide how to ship. When in doubt, use a laboratory courier or ground-based shipping. Contact the shipping company's 800 number for assistance in determining shipping group, packaging, and other information.

[1] For samples known or suspected to be flammable, corrosive, or reactive, consult with the shipping company's 800 number for assistance in determining quantity, shipping group, packaging, and other information. It is also wise to limit the sample size to only the quantity needed by the laboratory. Examples include the following:

- Corrosive, such as a cleaning solution known to be concentrated acid for trace metals analysis
- Reactive, such as a shovel-full of contaminated soil that fumes and sputters when exposed to air
- Reactive, such as a sample material became very warm when it got wet
- Flammable, such as a sample of the upper layer of soil where a gasoline spill was known to have occurred and a small amount of free liquid is visible in the bottom of the sample container

[2] Do not over-categorize a sample for which there is no information or observation indicating it is flammable, reactive, or corrosive. An example here would be soil from the clean margin of an excavation done to containerize a spill. It should not be categorized as flammable if there is no discoloration or free liquid.

[3] For concentrated samples for which a determination of flammable, corrosive, or reactive cannot be made, such as waste oil, err on the side of caution and use small quantities and secure packaging.

Environmental Compliance and Operations

Technical Instruction

ENV-TI-05.80.25

Monitoring Well and Piezometer Installation and Development

Revision 0003

Level of Use: Reference Use

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Prepared by: Environmental Compliance and Operations

Reviewed by: Donald W. Snodgrass Date: 08-22-2019

Concurred by: James Osborne Date: 08-28-2019

Concurred by: Brian S. Fowler Date: 08-28-2019

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0001	07-31-2018	I5, 35, 36	Added well information; added turbidity information.
0002	04-01-2019	20, 41	Added information about decontamination requirements in active CCR material sites.
0003	09-16-2019	All	Changes throughout.

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1.0 PURPOSE

This Technical Instruction (TI) describes requirements, specific techniques, and methods to be followed in order to ensure consistent installation and development of monitoring wells (MW) that are to be used to collect groundwater samples; and consistent installation of piezometers (PZ) used to measure hydraulic head. This TI is applicable to subsurface drilling, MW construction and completion, and PZ construction and completion.

Subsurface drilling is to be conducted using one of the following drilling techniques:

- Hollow-stem auger drilling
- Air rotary drilling
- Sonic drilling
- Mud rotary drilling

Field personnel conducting drilling activities are required to be familiar with the procedures provided in this TI. The requirements for TVA well drilling, using the methods listed above, are included in this TI. If field personnel determine that the procedures described in this section are either inappropriate, inadequate, or impractical and that another procedure must be used for any aspect of the design, construction and/or installation of a groundwater MW, the variant procedure must be approved by the TVA Project Manager, in writing, and documented in the field log book, along with a description of the circumstances requiring its use.

2.0 SCOPE

A. This TI applies to TVA employees and contractors who perform MW installation, PZ installation, or MW and PZ development procedures related to the TVA coal combustion residual management program.

B. This TI was developed under the general guidelines of the Environmental Protection Agency (EPA), SESGUID-101-R1, Design and Installation of Monitoring Wells.

Review Cadence: This TI will be reviewed every four years with the review documented in the Revision Log.

3.0 PRECAUTIONS/LIMITATIONS

3.1 Precautions

None

3.2 Limitations

None

4.0 REFERENCES

4.1 Performance References

A. ASTM Standard D5092/D5092M-16, Design and Installation of Ground Water Monitoring Wells, 2016 in Aquifers

B. ENV-TI-05.80.03, Field Record Keeping

C. ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination

D. TVA-SPP-18.005, Plan Jobs Safely

E. US EPA, EPA/540/S-95/503, Nonaqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling, and Remediation, 1995

F. US EPA, Region 4, SESGUID-101-R1, Design and Installation of Monitoring Wells, 2013

G. US EPA, Region 4, SESDPROC-105-R2R3, Groundwater Level and Well Depth Measurement, 2016

H. US EPA, Region 1, EQASOP-GW4, Revision 4, Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells, 2017

4.2 Developmental References

A. ASTM D5092-4(2010)e1/5092M-16, ASTM International, Design and Installation of Groundwater Monitoring Wells

B. ENV-TI-05.80.42, Groundwater Sampling

C. ENV-TI-05.80.01, Planning Sampling Events

D. US EPA, Region 4, SESDPROC-105-R2R3, Groundwater Level and Well Depth Measurement, 2016

4.2 Developmental References (continued)

E. US EPA, Region 1, EQASOP-GW4, Revision 4, Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells, 2017

F. USACE, Engineer Manual 1110-1-4000, Engineering and Design: Monitoring Well Design, Installation, and Documentation at Hazardous Toxic, and Radioactive Waste Sites, 1998

4.3 Commitments

None

5.0 PREREQUISITE ACTIONS

None

6.0 PERFORMANCE

6.1 General Considerations

A. Proper safety precautions must be observed when constructing and installing groundwater MWs. When using this procedure, minimize exposure to potential health hazards through the use of protective clothing, eye wear, hearing protection, and gloves. Site-specific health and safety requirements are included in the site-specific health and safety plan prepared by each sampling contractor.

B. All field activities are to be documented by the Field Team Leader, or designee, in accordance with TVA-ENV-TI-05.80.03, Field Record Keeping.

C. Field work must be properly documented. Depending on the requirements of your organization, there are different mechanisms for recording. You must meet the requirements for your specific organization.

1. Groundwater Application, or other electronic data collection system
2. Field logbooks
3. Field worksheets (see Attachment 1, Example - Preliminary Groundwater Data Field Worksheet)
4. Field notebooks
5. Data sheets

6.1 General Considerations (continued)

D. Field personnel conducting MW installation, PZ installation, or MW and PZ development are required to be familiar with the ENV-TI-05.80.XX series procedures.

E. Potential hazards associated with MW installation, PZ installation, or well development activities are to be thoroughly evaluated prior to conducting field activities. During planning and sampling activities, procedures to ensure safety will be incorporated, according to the TVA Standard Programs and Processes (SPP), TVA-SPP-18.005, Plan Jobs Safely, which provides information on using job safety analyses (JSAs) and pre-job briefings (PJBs).

F. Prior to intrusive subsurface activities, the appropriate utility notifications (that is, National 811, One Call) are to be made and the dates of intrusive activities are scheduled within the lawful dates provided by the One Call Center. The Field Team Leader is to verify, to the extent practicable, that utilities have responded to the One Call request and have marked their respective utility. If there is uncertainty associated with potentially unmarked utilities, the Field Team Leader must suspend work until the issues can be resolved. The Field Team Leader must also contact plant personnel to obtain clearance for drilling locations on TVA property.

G. Care must be taken to avoid contamination or cross-contamination during MW installation, PZ installation, or MW and PZ development. This is accomplished primarily by decontaminating all drilling tools, rods, rigs, groundwater pumps, surge blocks, or other development tools, between boreholes, during installation activities and between wells and PZ during development activities, in accordance with ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination.

H. Well installation personnel must wear powder-free nitrile gloves while installing MWs and PZs. Specifically, nitrile gloves are worn while handling the well screen, or, as necessary, to prevent the possibility of cross-contamination with the well screen.

I. Prior to field activities, the field team must consider how investigation-derived waste (IDW); such as drill cuttings, purge water, and decontamination fluids, is to be handled. Refer to Section 6.19 for specific IDW handling procedures.

6.2 Safety Procedures for Drilling Activities

A. The driller and designated safety person are to be responsible for the safety of the drilling team performing the drilling activities. All personnel conducting drilling activities are to be qualified in proper drilling and safety procedures. Before any drilling activity is initiated, utilities must be marked or cleared by the appropriate state or municipal utility protection organization.

B. At an absolute minimum, the following safety requirements will be adhered to while performing drilling activities. The safety requirements specified below are not intended to be, nor should be assumed to be, all inclusive:

1. All drilling personnel will wear safety hats, safety glasses, and steel toed boots. Additionally, hearing protection, such as ear plugs, are required and will be provided by the drilling contractor.

2. Work gloves (cotton, leather, etc.) are to be worn when working around or while handling drilling equipment. Nitrile gloves are to be worn while installing MW and PZ, handling the well screen, or as necessary, to prevent the possibility of cross-contamination with the well screen.

3. All personnel directly involved with the drilling rig(s) are to know where the kill switch(s) is located in case of emergencies, and verify the kill switches are functioning daily.

4. All personnel are to stay clear of the drill rods or augers while in motion, and are not to grab or attempt to attach a tool to the drill rods or augers until they have completely stopped rotating.

5. Do not hold drill rods or any part of the safety hammer assembly collecting standard penetration test samples or while the hammer is in operation.

6. Do not lean against the drill rig or place hands on or near moving parts at the rear of the rig while it is operating.

7. Keep the drilling area clear of any excess debris, tools, or drilling equipment.

8. The driller will direct all drilling activities. No work on the rig or work on the drill site will be conducted outside of the driller's direction. Overall drill site activities will be in consultation with the lead field geologist or engineer.

9. Each drill rig will have a first-aid kit and at least one fire extinguisher located on the rig in a location quickly accessible for emergencies. All drilling personnel will be familiarized with the location of the fire extinguishers and first-aid kit.

10. Work clothes will be form fitting, but comfortable and free of straps, loose ends, strings etc., that might catch on some moving part of the drill rig.

6.2 Safety Procedures for Drilling Activities (continued)

11. Rings, watches, or other jewelry will not be worn while working around the drill rig.

12. The drill rig will not be operated within a minimum distance of 20 feet of overhead electrical power lines and/or buried utilities that might cause a safety hazard. In addition, the drill rig will not be operated while there is lightening in the area of the drilling site. If an electrical storm moves in during drilling activities, the area will be vacated until it is safe to return.

6.3 Pre-Field Preparation

A. This section documents procedures and methods associated with subsurface drilling, MW construction and completion, and PZ construction and completion. Any variation in these procedures must be approved by the TVA Project Manager, in writing, and must be fully documented in the field logbook. Field work cannot progress until deviations are approved or resolved.

B. The Field Team Lead is responsible for ensuring that the following activities are completed before traveling to the site:

1. Review facility-specific Sampling and Analysis Plan (SAP) to determine the number and locations of MWs and PZs to be installed or developed.

2. Obtain site maps with planned boring locations clearly identified.

3. Review Job Safety Analysis (JSA) Worksheet – Form 15943 and identify needed safety equipment. Conduct a Pre-Job meeting prior to beginning work and document on the Pre-Job Brief Checklist – Form 40898. Once the work activities are complete conduct a post-job meeting and document the meeting using the Post-Job Review Checklist - Form 40899.

4. Obtain utility clearance for subsurface excavation/penetration locations, as required.

5. Identify tools and other items needed for the field event. Obtain equipment necessary for completing the installation or development. Refer to Attachment 1, Recommended Well Depth Measurement Equipment and Materials Checklist, for an example checklist of equipment and materials. It is important to note that the items on Attachment 1 are not intended to be all inclusive, and the preparation of an event-specific checklist of equipment and materials is highly recommended.

6. Verify with the TVA Project Manager that the appropriate number of solid and liquid U.S. Department of Transportation (DOT)-approved drums, or other suitable containers, is available for disposal of investigation-derived soil cuttings.

6.3 Pre-Field Preparation (continued)

7. Ensure all reusable equipment has been decontaminated, in accordance with TVA-ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination, for decontamination instructions.

8. Pre-identify any potential site access logistical issues and take actions to address them.

9. Obtain name and phone number of the site contact in case questions arise about the installation process.

6.4 Field Preparation

Prior to beginning work at the collection site, the Field Team Leader shall ensure that the following activities have been completed:

A. Locate and mark planned well locations and verify utility clearance has been performed prior to intrusive subsurface drilling deeper than one foot. Verify that the appropriate utility clearance service has marked utilities at drilling locations. Confirm with the TVA Project Manager that clearance and right-of-access permission has been obtained. Document clearance activities and utility markings in the field logbook and request sign-offs from the TVA Project Manager.

B. Pre-identify any potential site access logistical issues. Note any slope stability, overhead obstruction, or other physical constraints that could hinder or preclude drilling activities. Notify the TVA Project Manager of any identified drilling issues and provide recommendations for any relocation based on field observations.

C. Establish the decontamination area away from (and preferably up wind of) potentially contaminated areas, where possible. Decontaminate non-disposable sampling equipment and downhole tools that may come in contact with the sample matrix, prior to use, in accordance with TVA-ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination.

D. Obtain potable water for decontamination. Record the water source in the field logbook. Obtain approval for using on-site water for decontamination from the TVA Project Manager, prior to use.

6.5 Drilling Methods

Drilling methods are to be used to install environmental MWs or PZs under various subsurface conditions. In all cases, the preferred methods are those that case the hole during drilling; i.e., Hollow Stem Augers (HSA) and sonic methods using an override system. Other methods are to be used where specific subsurface or project criteria dictate.

6.5.1 Hollow Stem Auger

This type of auger consists of a hollow, steel stem or shaft, with a continuous, spiraled steel flight, welded onto the exterior. A hollow auger bit, generally with carbide teeth, disturbs soil material, when rotated, whereupon the spiral flights transport the cuttings to the surface. This method is best suited in soils that have a tendency to collapse when disturbed. A MW can be installed inside of hollow-stem augers with little or no concern for the caving potential of the soils. If caving sands exist during MW installations, a drilling rig must be used that has enough power to extract the augers from the borehole without having to rotate them. A bottom plug, trap door, or pilot bit assembly can be used at the bottom of the augers to keep out most of the soils and/or water that have a tendency to enter the bottom of the augers during drilling. Potable water (analyzed for contaminants of concern) may be poured into the augers during drilling to equalize pressure so that the inflow of formation materials will be held to a minimum. Water-tight center bits are not acceptable because they create suction when extracted from the augers. This suction forces, or pulls, cuttings and formation materials into the augers, defeating the purpose of the center plug. Augering without a center plug or pilot bit assembly is permitted, provided that the soil plug, formed in the bottom of the augers, is removed before sampling or installing well casings. Removing the soil plug from the augers can be accomplished by drilling and washing out the plug, using a rotary bit, or augering out the plug with a solid-stem auger bit sized to fit inside the hollow-stem auger. Bottom plugs can be used where no soil sampling is conducted during the drilling process. The bottom plug is wedged into the bottom of the auger bit and is knocked out at depth with drill pipe or the weight of the casing and screen assembly. The plug material is to be compatible with the screen and casing materials. The use of wood-bottom plugs is not acceptable. The type of bottom plug, trap door, or pilot bit assembly proposed for the drilling activity is to be approved by a lead field geologist prior to drilling operations. Boreholes can be augered to depths of 150 feet or more, depending on the auger size, but generally boreholes are augered to depths less than 100 feet.

6.5.2 Solid Stem Auger

A. This type of auger consists of a sealed hollow or solid stem or shaft with a continuous spiraled steel flight welded on the outside of the stem. An auger bit connected to the bottom disturbs soil material when rotated and the spiral flights transport cuttings to the surface. At the desired depth, the entire auger string is removed to gain access to the bottom of the borehole. This auger method is used in cohesive and semi-cohesive soils that do not have a tendency to collapse when disturbed. Boreholes can be augered to depths of 200 feet or more, depending on the auger size, but generally boreholes are augered to depths less than 100 feet.

B. Sections 6.5.1 and 6.5.2 can be used in unconsolidated soils and semi-consolidated (weathered rock) soils, but not in competent rock.

C. Each method can be employed without introducing foreign materials, such as water and drilling fluids, into the borehole, minimizing the potential for cross-contamination. Minimizing the risk of cross contamination is one of the most important factors to consider when selecting the appropriate drilling method(s) for a project.

6.5.3 Sonic Methods

A. Sonic methods generally alternately advance concentric hollow drill stems using rotation, in conjunction with axial vibration of the drill stem. After each stage of drill stem advancement, the inner string is removed with a core of drill cuttings, while the outer override string remains to hold the borehole open. The cuttings can be removed nearly intact from the inner casing for examination of the stratigraphy, prior to sampling or disposal. Because there are no auger flights to increase the borehole diameter, the quantity of cuttings removed from the hole is minimized, as compared to hollow stem augering. With moderate rotation, smearing of the formation materials on the borehole walls is reduced, as well. This drilling method is useful in a variety of materials, from flowing sands to heavily consolidated or indurated formations.

B. In flowing sands, the drill casings can be filled and/or pressurized with potable water to prevent excess entry of formation materials into the drill string. The same QA/QC requirements for sampling of material introduced to the borehole apply, as in other drilling methods. Because the amount of water introduced into the borehole can be significant, an approximation of the water used in the drilling process is to be logged for use in estimating appropriate well development withdrawal.

6.5.3 Sonic Methods (continued)

C. Sonic drilling allows a larger-diameter, temporary casing to be set into a confining layer, while drilling proceeds into deeper aquifers. This temporary casing is then removed during the grouting operation. In many cases, the use of temporary casing for sealing off upper aquifers is an acceptable approach. However, the level of contamination in the upper aquifer, the importance of the lower aquifers for drinking water uses, the permeability and continuity of the confining layer, and state regulations are to be taken into account when specifying this practice, as opposed to permanent outer casing placed into the confining unit. Note that when using the temporary casing practice, it is critical that grout be mixed and placed properly.

D. Because the total borehole diameter in sonic drilling is only incrementally larger than the inner casing diameter, particular care is to be taken that the well casing is placed in the center of the drill stem, while placing the filter pack. Centralizers are to be used in most cases to facilitate centering, particularly in the case of deep wells with PVC casing.

6.5.4 Rotary Methods

A. Rotary methods consist of a drill pipe or drill stem coupled to a drilling bit that rotates and cuts through the soils. The cuttings produced from the rotation of the drilling bit are transported to the surface by drilling fluids which generally consist of water, drilling mud, or air. The water, drilling mud, or air are forced down through the drill pipe, and out through the bottom of the drilling bit. The cuttings are then lifted to the surface between the borehole wall and the drill pipe, or within a concentric drill stem in reverse rotary. Except in the case of air rotary, the drilling fluid provides a hydrostatic pressure that reduces or prevents borehole collapse. When considering this method, it is important to evaluate the potential for contamination when fluids and/or air are introduced into the borehole.

B. Due to the introduction of the various circulating fluids, the use of rotary methods requires that the potential for contamination by these fluids be evaluated. Water and mud rotary methods present the possibility of trace contamination of halogenated compounds when municipal water supplies are used as a potable water source. Air rotary drilling can introduce contamination through the use of lubricants or entrained material in the air stream. Unless contaminated formations are cased off, the circulation of drilling fluids presents a danger of cross contamination between formations. In any of the rotary (or sonic) methods, care must be exercised in the selection and use of compounds to prevent galling of drill stem threads.

6.5.5 Water Rotary

When using water rotary, potable water (that has been analyzed for contaminants of concern) is to be used. If potable water (or higher- quality water) is not available on-site, then potable water will have to be transported to the site or an alternative drilling method will have to be selected. Water does not clog the formation materials, but the suspended drilling fines can be carried into the formation, resulting in a very difficult-to-develop well. This method is most appropriate for setting isolation casing.

6.5.6 Air Rotary

A. Air rotary drilling uses air as a drilling fluid to entrain cuttings and carry them to the surface. High air velocities, and consequently large air volumes and compressor horsepower are required. Down-the-hole (DTH) percussion hammers, driven by the air stream, can be used with this method to rapidly penetrate bedrock materials. Where a casing through unconsolidated material is required to prevent borehole collapse, it can be driven in conjunction with advancement of the drill stem.

B. When using air rotary drilling in any zone of potential contamination, the cuttings exiting the borehole must be controlled. This can be done using the dual-tube reverse circulation method where cuttings are carried to the surface inside dual-wall drill pipe and separated with a cyclone separator. An air diverter with hose or pipe carrying cuttings to a waste container is also an acceptable alternative. Allowing cuttings to blow uncontrolled from the borehole is not acceptable.

C. When using air rotary, the issue of contaminants being introduced into the borehole by the air stream must be addressed. Screw compressor systems are to have a coalescing filter system in good working order to capture excess entrained compressor oils. The lubricant to be used with DTH hammers, as well as thread lubricants to be used on drill stem, is to be evaluated for their potential impact on analytical samples.

6.5.7 Mud Rotary

Mud rotary is an undesirable drilling method because contamination can be introduced into the borehole from the constituents in the drilling mud, cross-contamination can occur along the borehole column, and it is difficult to remove the drilling mud from the borehole after drilling and during well development. The drilling mud can also carry contaminates from a contaminated zone to an uncontaminated zone, thereby cross-contaminating the borehole. If mud rotary is selected, only potable water and pure, no additives, bentonite drilling muds are to be used. All materials used are to have adequate documentation as to manufacturer's recommendations and product constituents. QA/QC samples of drilling muds and potable water are to be collected at a point of discharge from the circulation system to assure that pumps and piping systems are not contributing cross-contamination from previous use.

6.6 Borehole Construction

A. The borehole or hollow stem auger is to be of sufficient diameter so that well construction can proceed without major difficulties. For open boreholes, the annular space around the riser and screen is to be approximately two inches to allow the uniform deposition of well materials around the screen and riser, and to allow the passage of tremie pipes and well materials, without unduly disturbing the borehole wall. For example, a two- inch nominal diameter casing would require a six- inch inside diameter (ID) borehole.

B. In hollow stem augers and sonic method drill casing, the ID is to be of sufficient size to allow the passage of the tremie pipe to be used for well grout placement, as well as free passage of filter sands or bentonite pellets dropped through the auger or casing. In general, 4 1/4 inches ID is to be the minimum size used for placement of two inches nominal casing and 8 1/4 inches ID for four inches nominal casing. Larger augers are to be used where installation difficulties, due to geologic conditions or greater depths, are anticipated; e.g., larger augers might be required to place a bentonite pellet seal through a long water column.

6.7 Over-Drilling the Borehole

Sometimes it is necessary to over-drill the borehole in anticipation of material entering the augers during center bit removal or knocking out of the bottom plug. Normally, three to five feet is sufficient for over-drilling. The borehole can also be over-drilled to allow for an extra space, or a sump area, below the well screen. This sump area provides a space to attach a five- or ten-foot section of well casing to the bottom of the well screen. The extra space, or sump, below the well screen serves as a catch basin or storage area for sediment that flows into the well and drops out of suspension. These sumps are added to the well screens when the wells are screened in aquifers that are naturally turbid and will not yield clear formation water (free of visible sediment) even after extensive development. The sediment can then be periodically pumped out of the sump, preventing the well screen from clogging or silting up. If the borehole is inadvertently drilled deeper than desired, it can be backfilled to the design depth with bentonite pellets, chips, or the filter sand that is to be used for the filter pack.

6.8 Filter Pack Placement

When placing the filter pack into the borehole, a minimum of six inches of the filter pack material is to be placed under the bottom of the well screen to provide a firm base. Also, the filter pack is to extend a minimum of two feet above the top of the well screen to allow for settling and to isolate the screened interval from the grouting material. In open boreholes, the filter pack is to be placed by the tremie or positive displacement method. Placing the filter pack by pouring the sand into an open drill stem is acceptable with the use of hollow stem augers and other methods where the borehole is temporarily cased down to the filter pack.

6.9 Filter Pack Seal – Bentonite Pellet Seal (Plug)

A. Bentonite pellets consist of ground, dried bentonite compacted into pellets available in several sizes. Bentonite pellets are compressed to a bulk density of 70-80 lb/ft^3 and hydrate to a 30 percent minimum solids material. Where neat cement grouts are to be used, the placement of a bentonite pellet seal above the filter pack is mandatory to prevent the possibility of grout infiltration into the screened interval prior to setting. Bentonite chips or other sealing products will not be substituted in this application. Where bentonite grouts are to be used, the placement of a bentonite pellet seal is optional, but desirable.

B. Since bentonite pellets begin hydrating rapidly, they can be very difficult to place properly. They are generally placed by pouring slowly into open boreholes, hollow stem augers or sonic drill pipe. In some cases, pellets are placed by tremie pipe and flushed into place with potable water. A tamper can be used to ensure that the material is being placed properly and to rapidly break up any pellet bridging that occurs.

6.9 Filter Pack Seal – Bentonite Pellet Seal (Plug) (continued)

C. Pellet seals will be designed for a two-foot thickness of dry pellets above the filter pack. Hydration may extend the height of the seal. Where neat cement grouts are to be used, the pellets are to be hydrated for eight hours, or the manufacturer's recommended hydration time, whichever is greater. Where the water table is temporarily below the pellet seal, potable (or higher quality) water is to be added repeatedly to hydrate the pellets prior to grouting.

6.10 Grouting the Annular Space

A. The annular space between the casing and the borehole wall is to be filled with either a 30 percent solids bentonite grout, a neat cement grout, or a cement/bentonite grout. Each type of grout selected will be evaluated as to its intended use and integrity. Bentonite grouts are preferred, unless the application dictates the use of another material.

B. Bentonite grout is to be a 30 percent solid pure bentonite grout. Drilling muds are not acceptable for grouting. The grout is to be placed into the borehole, by the tremie method, from the top of the bentonite seal to within two feet of the ground surface or below the frost line, whichever is the greater depth. The bentonite pellet seal or filter pack will not be disturbed during grout placement, either by the use of a side discharge port on the tremie tube, or by maintaining clearance between the bottom of the tremie tube and the bentonite seal or filter pack. The grout must be allowed to cure for a minimum of 24 hours before the concrete surface pad is installed. The preferred method of achieving proper solids content is by measurement of ingredients per the manufacturer's specifications during mixing with a final check by grout balance after mixing. Bentonite grouts are to have a minimum density of 10 lb/gal to ensure proper gelling and low permeability. The density of the first batch of grout will be measured, while mixing, to verify proper measurement of ingredients. Estimating the grout density is not acceptable.

C. Cement grouts are generally dictated where a high level of dissolved solids or a particular dissolved constituent would prevent proper gelling of a bentonite grout. Neat cement grouts (cement without additives) are to be mixed using six gallons of water per 94 lb bag of Type 1 Portland cement to a density of 15 lb/gal. The addition of bentonite (5 to 10 percent) to the cement grout can be used to delay the setting time and may not be needed in all applications. The specific mixtures and other types of cement and/or grout proposed are to be evaluated on a case-by-case basis by a lead field geologist.

6.11 Monitoring Well Installation

A. The borehole will be bored, drilled, or augered as close to vertical as possible, and checked with a plumb bob or level. Deviation from plumb is to be within one degree per 50 feet of depth. Slanted boreholes are undesirable and are to be noted in the boring logs and final construction logs. The depth and volume of the borehole, including the over-drilling, if applicable, will have been calculated and the appropriate materials procured prior to drilling activities.

B. The well casings are to be secured to the well screen by flush-jointed threads and placed into the borehole and plumbed by the use of centralizers and/or a plumb bob and level. Another method of placing the well screen and casings into the borehole, and plumbing them at the same time, is to suspend the string of well screen and casings in the borehole by means of a hoist on the drill rig. This wireline method is especially useful if the borehole is deep and a long string of well screen and casings have to be set and plumbed.

C. No lubricating oils or grease are to be used on casing threads. No glue of any type is to be used to secure casing joints. Teflon O-rings can be used to ensure a tight fit and minimize leakage.

D. Before the well screen and casings are placed on the bottom of the borehole, at least six inches of filter material is to be placed at the bottom of the borehole to serve as a firm footing. The string of well screen and casings will then be placed into the borehole and plumbed. Centralizers can be used to plumb a well, but centralizers are to be placed so that the placement of the filter pack, bentonite pellet seal, and annular grout will not be hindered. Centralizers placed in the wrong locations can cause bridging during material placement. MWs less than 50 feet deep generally do not need centralizers. If centralizers are used, they are to be placed below the well screen and above the bentonite pellet seal. The specific placement intervals are to be decided based on site conditions.

E. When installing the well screen and casings through hollow-stem augers, the augers are to be slowly extracted as the filter pack, bentonite pellet seal, and grout are tremied and/or poured into place. The gradual extraction of the augers will allow the materials being placed in the augers to flow out of the bottom of the augers into the borehole. If the augers are not gradually extracted, the materials (sand, pellets, etc.) will accumulate at the bottom of the augers, causing potential bridging problems.

6.11 Monitoring Well Installation (continued)

F. After the string of well screen and casing is plumb, the filter pack material will then be placed around the well screen to the designated depth. With cased drilling methods, the sand is to be poured into the casing or augers until the lower portion is filled. The casing or augers are then withdrawn, allowing the sand to flow into the evacuated space. With hollow stem augers, sand is to always fill the augers at 6- to 12-inch intervals, ensured by pouring the sand, while checking the level with a weighted tag line. The filter pack sand in open boreholes is to be installed by tremie methods, using water to wash the sand through the pipe to the point of placement.

G. After the filter pack has been installed, the bentonite pellet seal, if used, is to be placed directly on top of the filter pack to an unhydrated thickness of two feet. When installing the seal for use with cement grouts, the bentonite pellet seal is to be allowed to hydrate a minimum of eight hours or the manufacturer's recommended hydration time, whichever is longer.

H. After the pellet seal has hydrated for the specified time, the grout will then be pumped by the tremie method into the annular space around the casings. The grout will be allowed to set for a minimum of 24 hours before the surface pad and protective casing are installed.

I. The general borehole advancement and MW installation procedures are described below:

1. Decontaminate the drill rods, tools, drill bits, and split spoons prior to advancement at each borehole on a decontamination pad or designated decontamination area. The decontamination pad is typically constructed of polyethylene sheeting placed over a series of straw bales or other structure. The decontamination pad is located downwind or down gradient of proposed (marked) well locations and existing MWs. Wastes generated during decontamination are managed in accordance with Section 6.19. If drilling in active CCR material sites, it may be acceptable to decontaminate drill rods, tools, drill bits and split spoons in a decontamination area within the active CCR site but away from any MWs without catching the decontamination fluid. This should be verified with the Plant’s waste management procedures.

2. Mobilize drilling rig to the marked location, set up the exclusion or safety zone, and construct a plastic-lined fluid collection area, if necessary.

3. If required, obtain the anticipated number of 55-gallon drums needed to contain the overburden and rock cuttings, drilling fluids, purged groundwater, and decontamination waste. Position the drums so the drums can be removed or staged.

6.11 Monitoring Well Installation (continued)

4. Use shrouds, canopies, or directional pipes to contain and direct the drill cuttings and fluids into the fluid collection area or 55-gallon drums, as necessary.

5. Visually screen the soil cuttings and liquid obtained from the uppermost water-bearing zone for signs of potential site impacts. Note the results in the field logbook. Retain the samples from the representative well borehole onsite for inspection until completion of the characterization activities.

6. Log drill cuttings and/or split spoon samples to ensure consistent lithologic descriptions are made during borehole advancement activities. Refer to Section 6.18 for further description of the appropriate observations and documentation.

7. If a borehole is not completed the same day that it is started, secure the borehole overnight by leaving the drill rod in the borehole or by placing a temporary cap on the well or borehole.

8. Bore, drill, or auger the borehole as close to vertical as possible and check with a plumb bob or level. Deviation from plumb is to be within one degree per 50 feet of depth.

9. Minimize use of joint lubrication compounds. If these lubrication compounds are required, record the joint compound used; such as brand name, chemical composition, and amount used, into the field logbook. Food-grade lubrication compounds are preferred. Petroleum-based lubrication compounds are not acceptable for use as joint lubrication.

10. Use rigid PVC materials, meeting National Sanitary Foundation (NSF) Standard 14-type well casing, for groundwater MWs. Use PVC well casing that is flush threaded. A protective steel casing with a lockable cap is installed at least three feet into the grout seal of each MW installed with a stickup casing. Flush-mounted casings are constructed using a flush-mounted steel vault mounted within a cement-concrete skirt. Flush-mounted finished wells are fitted with a locking, water-tight cap and a padlock. Above-ground finished wells are fitted with a water-tight cap and padlock. The PVC is notched to allow for natural water level fluctuations. Above ground riser and flush mount details are provided in Section 6.13.

11. Care is taken to allow for an appropriate vertical clearance between the inner casing and well cap to allow for installation of down-hole monitoring equipment.

12. Keys to locks are given to the Field Team Leader who places the keys in the project files upon returning from the field.

6.11 Monitoring Well Installation (continued)

13. Verify that at least two inches of annular space are available between the casing and the borehole or between two casings to allow sufficient space for emplacement of the sand pack and/or the annular seal. Grouts or slurries used for annular seals are emplaced using a tremie pipe. Bentonite pellets, chips, or powder may be poured in from the top of the well but are poured slowly to prevent bridging. If bentonite pellets are used, they are to be less than 1/5 the width of the annular space, also to prevent bridging.

14. Intermittent sounding (using a weighted tape measure) of the top of solid annular materials is conducted and documented in the field logbook.

15. Install a cement pad around the base of each protective casing. Document the well number, depth, yield, and the completion date in the field logbook and record on the inside cover of the well. Permanently mark the well number (and permit number, if applicable) on the outer protective casing. Construction details for the cement well pad are provided in Section 6.13.

16. After the well is completed, establish the location and elevation of the well, relative to a standard datum. Accurately locate the MW and reference to a vertical datum by a licensed surveyor.

6.11.1 Overburden Monitoring Well Installation Using Hollow-Stem Auger

A. At sites where groundwater is anticipated to be present in unconsolidated surficial material, MWs are installed using hollow-stem augers. One two-foot split-spoon sample is collected per each five-foot interval, or at smaller intervals, if changes in subsurface lithology or a water horizon are encountered. In general, continuous split-spoon samples are collected at a minimum of one well boring associated with each site area. Specific sampling requirements will be detailed in the site-specific sampling and analysis plan.

B. The vertical placement of the well screen within a borehole is dependent upon the purpose of the well, site hydrogeologic conditions, and the physical and chemical characteristics of potential contaminants. The TVA Project Manager confirms well construction (well screen depth, length, and diameter) with the Field Team Leader. Groundwater MWs installed in the unconsolidated materials are often designed to screen the water table to ensure that free-phase floating products are detected, if present.

   1. After the borehole is drilled to the desired depth, gently lower the well screen and casing assembly through the augers to the bottom of the borehole, and gradually remove the auger string from the borehole, while simultaneously filling the annulus with the appropriately-sized clean, uniform sand.

   2. The appropriate sand size and screen slot size are based on the formation's grain size distribution. For fine grain soils, the screen is 10 slot (0.010-inch opening) and the sand pack is made of number 0 Morie sand or equivalent. For coarse grain soil, the screen is 20 slot (0.020-inch opening) and the sand pack is made of number 1 Morie sand, or equivalent.

   3. In the event that the borehole walls are unstable or in flowing sand condition, use a plug at the bottom of the auger string to prevent native material from entering the annulus. This plug is punched out prior to backfilling the annulus.

   4. Place a cap or cover over the top of the PVC well casing, or riser, before pouring the sand pack to prevent any filter pack materials or sealing materials from falling inside the well.

   5. Fill the annular space around the screen to a minimum of two feet above the top of the screen.

   6. The Field Team Leader is made aware of sticking problems when withdrawing the auger from the borehole. Reasonable force can be applied if the screen is stuck in the auger; however, too much force can cause damage to the screen, which is pulled for inspection if this occurs.

6.11.1 Overburden Monitoring Well Installation Using Hollow-Stem Auger (continued)

7. To ensure that the sand pack provides an adequate cover over the screen, determine the depth to the top of the sand pack with a weighted tape.

8. Consideration is also given to the use of engineered screens (pre-packed) to ensure proper well installation.

9. When the sand pack is at the desired level, place a minimum 2-foot layer of bentonite on the sand pack. Apply the bentonite, either via tremie pipe or by slowly pouring pellets (coated, if placed below the water table), down the annulus to minimize bridging. To prevent bridging, the pellets are 1/5 the size of the annulus. For a two-inch well, the annulus is two inches and the pellets are less than 0.4 inches. The bentonite is to be composed of sodium montmorillonite, purchased from a commercial source, and documented, as such, on the completed well construction diagram.

10. If the pellets are placed above the water table, potable water is added to the annulus. If the sides of the borehole are unstable or there are problems with using pellets, a slurry is mixed at a ratio of 1.5 pounds of bentonite per gallon of water and emplaced using a tremie pipe. The slurry is initially directed into a bucket to determine if the mixture is suitable for pumping.

11. Measure the top of the bentonite seal with a weighted tape to verify that the proper thickness of the seal has been placed in the annulus.

12. Grout the remaining annular space with a Portland cement/bentonite mixture to ground surface. The grout mixture consists of approximately four pounds of pure bentonite per 94-pound bag of Portland cement with six to seven gallons of potable water. The mixture is pumped through a tremie pipe until undiluted grout rises from the annulus to the ground surface.

13. Record well construction details and soil boring information in the field book or boring log forms, per Section 6.17.

6.11.2 Air Rotary Drilling/Bedrock and Overburden Monitoring Well Installation

A. Air rotary, or percussion drilling techniques, are used to install both shallow and deep bedrock MWs and overburden wells; however, air rotary is only used for overburden wells when hollow-stem augering techniques fail. Potable water can be added to the borehole, if required, for dust control. The source of the potable water is noted in the field notebook. The well construction detail and soil boring information is also recorded in the field book and on Attachment 2, Example - Boring Log, and Attachment 3, Example - Monitoring Well Installation Field Log.

B. Shallow Bedrock Well Construction (Single-Cased)

1. A shallow bedrock MW is typically located in the first significant water-bearing zone encountered in bedrock.

2. To construct a shallow bedrock MW, use air rotary techniques to drill a ten-inch diameter borehole, unless specified otherwise in project-specific control documents, through the overburden to a minimum of three feet into competent bedrock.

3. Collect cuttings every five feet, or more frequently, as necessary, to describe the subsurface conditions.

4. If saturated conditions are observed near the soil/bedrock interface and the objective is to monitor the uppermost water-bearing unit, a waiting period may be required prior to casing installation to assess static groundwater conditions. As appropriate, the borehole may be completed as a single-cased, screened well if water is observed to enter the borehole after a waiting period. If water is not observed in the borehole after the waiting period, a six-inch diameter well casing is installed at least five feet into competent bedrock to approximately two feet above ground surface.

5. Seal the annular space around the casing by pumping grout through a tremie pipe from the base of the borehole to ground surface. The grout consists of four pounds of pure powdered bentonite for each 94-pound bag of Portland cement, mixed with six to seven gallons of potable water.

6. After grouting of the casing, do not drill in the well until the grout has cured in that well (a minimum of 24 hours). The Field Team Leader determines when drilling can proceed.

6.11.2 Air Rotary Drilling/Bedrock and Overburden Monitoring Well Installation (continued)

7. Drill a nominal five-inch diameter open borehole below the base of the six-inch casing and complete as an open borehole or screened well. Drilling advances the borehole until a quantity of water, sufficient for sampling, is encountered. A recovery period may be required if the borehole produces very low yields.

8. Record well construction details and soil boring information in the field book and on Attachment 2, Example - Boring Log.

C. Deep Bedrock Well Construction (Double-Cased)

1. A deep bedrock MW is typically located in a water-bearing zone below the shallow bedrock water-bearing zone. In some cases, deep bedrock MWs may require double casing.

2. Drill a minimum 14-inch diameter borehole, unless specified otherwise in project-specific control documents, through the unconsolidated material to at least five feet into competent bedrock. Collect representative cuttings at least every five feet, or more frequently, as required, to describe the subsurface conditions.

3. Install a ten-inch diameter well casing and tremie-grout in place from the base of the borehole to the ground surface. Cut off this casing at 6 inches above ground surface, unless specified otherwise in project-specific control documents.

4. Grout and curing times are consistent with the shallow well construction methods. After the grout has cured properly, drill a nine-inch diameter borehole through the casing to the top of the deep interval to be monitored.

5. A six-inch inner casing is either tremie-grouted through the annular space between the outer and inner casing, or pressure-grouted through the center of the casing by displacing the grout with pressurized potable water. The grout mixture and curing times are consistent with the shallow well construction specification.

6. After the grout seal has cured, drill a five-inch open borehole below the base of the casing to the specified water-bearing zone. Complete each deep well as an open borehole, unless the borehole is unstable, in which case the well is screened, as described in Section 6.11D.

7. Record well construction details and soil boring information in the field book and Attachment 2, Example - Boring Log.

6.11.2 Air Rotary Drilling/Bedrock and Overburden Monitoring Well Installation (continued)

D. Screened Bedrock Wells

1. If the sides of the open borehole are unstable during drilling, the MW is completed with a two-inch or four-inch diameter casing and screen. The annular space around the screen is packed with clean, uniform, commercially-bagged sand a minimum of two feet above the top of the screen. The screen is 10 slot (0.010-inch opening) with number 0 Morie sand, or equivalent.

2. A two-foot thick minimum layer of bentonite pellets, less than 1/5 the size of the annulus, is placed above the sand pack. The remaining annular space is tremie-grouted to the surface with cement/bentonite slurry, as described in Step 6.11.2B.5.

6.12 Mud Rotary Drilling

A. Mud rotary drilling may be used when borehole stability problems preclude the use of hollow-stem augering or air rotary methods.

B. Potable water and natural materials, such as bentonite powder, are used for drilling mud. A record of the specific mud type used, such as brand name, chemical composition, and amount used, are to be recorded in the field logbook and on Attachment 2, Example - Boring Log.

C. Steps are taken, to the extent possible, to avoid the use of the mud rotary drilling method in the potential water-producing zone of a potential well because this drilling method may impact well production and groundwater chemistry. Extended development may be required for groundwater MWs installed, using mud rotary drilling.

6.13 Well Protection

6.13.1 Flush-Mount Well Pad

A concrete surface pad is to be installed around each well at the same time as the outer protective casing is being installed. The surface pad is to be formed around the outer protective casing. Concrete is to be placed into the pad forms and into the borehole (on top of the grout) in one operation making a contiguous unit. The size of the concrete surface pad is dependent on the well casing size. If the well casing is two inches in diameter, the pad is to be 4 feet x 4 feet x 4 inches. If the well casing is four inches in diameter, the pad is to be 4 feet x 4 feet x 6 inches. Round concrete surface pads are also acceptable. The finished pad is to be slightly sloped so that drainage will flow away from the protective casing and off of the pad. A minimum of one-inch of the finished pad is to be below grade to prevent washing and undermining by soil erosion.

6.13.2 Above-Ground Riser Pipe

A. The well casing, when installed and grouted, will extend above the ground surface a minimum of 2.5 feet. A vent hole is to be drilled into the top of the well casing cap to permit pressure equalization, if applicable. An outer protective casing is to be installed into the borehole after the annular grout has cured for at least 24 hours. The outer protective casing is to be of steel construction with a hinged, locking cap. Generally, outer protective casings used over two-inch well casings are four inches square by five feet long. Similarly, protective casings used over four-inch well casings are six inches square and five feet long. Other types of protective casing, including those constructed of pipe, are also acceptable. All protective casings are to have sufficient clearance around the inner well casings, so that the outer protective casings will not come into contact with the inner well casings after installation. The protective casings are to have a weep hole to allow drainage of accumulated rain or spilled purge water. The weep hole is to be approximately 1/4-inch in diameter and drilled into the protective casings, just above the top of the concrete surface pad, to prevent water from standing inside of the protective casings. Protective casings, made of aluminum or other soft metals, are normally not acceptable because they are not strong enough to resist tampering. Aluminum protective casing may be used in very corrosive environments.

6.13.2 Above-Ground Riser Pipe (continued)

B. Prior to installing the protective casing, the bentonite grout in the borehole annulus is excavated to a depth of approximately two feet. The protective casing is installed by pouring concrete into the borehole on top of the grout. The protective casing is then pushed into the wet concrete and borehole a minimum of two feet. Extra concrete may be needed to fill the inside of the protective casing so that the level of the concrete inside of the protective casing is at, or above, the level of the surface pad. In areas where frost heave of the surface pad is possible, the protective casing will first be pressed into the top surface of the bentonite grout seal and concrete poured around the protective casing. A granular material, such as sand or pea gravel, can then be used to fill the space between the riser and protective casing. The use of granular material, instead of concrete between the protective casing and riser, will also facilitate the future conversion of the well to a flush-mount finish, if required. The protective casing is to extend above the ground surface to a height so that the top of the inner well casing is exposed when the protective casing is opened. At each site, all locks on the outer protective casings are to be keyed alike.

6.13.3 Surface Protection

A. A minimum of three bumper guards (bollards), consisting of hollow steel pipes, three to four inches in diameter and a minimum five-foot length, are to be installed. These bumper guards are to be installed to a minimum depth of two feet below the ground surface in a concrete footing and extend a minimum of three feet above ground surface. The guards are to be filled with concrete and painted with high visibility paint.

B. Placing bumper guards (bollards) into five-gallon buckets filled with concrete and then burying the buckets with bollards in the ground, is not an acceptable method for providing surface protection.

C. Substantial steel rails and/or other steel materials can be used in place of steel pipe. Welding bars between the bumper posts can provide additional strength and protection in high traffic areas, but the protective bumpers must not be connected to the protective casing.

6.14 Piezometer Installation

A. PZs are installed, in general, using the same procedures in Section 6.11 for MWs. Note that the intended purpose of PZs is to measure hydraulic head. PZs are never used to collect groundwater samples for chemical analysis.

B. PZs typically have a very short screen and filter zone located at a determined depth, so that they can represent the hydraulic head at a determined point in the aquifer (punctual PZ). However, there may be instances where it is desirable to measure the potentiometric surface throughout a water column (windowed PZ). The windowed PZ cannot be used to obtain information on vertical flows.

C. Punctual Piezometer

The punctual PZ consists of a filter tip (screen) joined to a riser pipe. Steps 6.14C.1 through 6.14C.3 are used for its installation.

1. Install the filter tip at the target depth for hydraulic head monitoring and place a bentonite seal above the sand to isolate the pore water pressure at the tip. The sand zone and bentonite seal are created the same, as detailed in Section 6.11.

2. Backfill the annular space between the riser pipe and the borehole to the surface with a bentonite grout to prevent unwanted vertical migration of water.

3. Terminate the riser pipe above ground level with a vented cap.

D. Windowed Piezometer

The following procedure is used for installation of the windowed PZ.

1. Construct the windowed PZ, using the same materials as the punctual PZ, but install without a bentonite seal; rather, backfill the borehole with gravel or sand.

2. Seal the top of the borehole to prevent the entry of surface runoff, and terminate the riser pipe above ground level.

6.15 Well Construction Materials

Well construction materials are chosen based on the goals and objectives of the proposed monitoring program and the geologic conditions at the site(s). In Section 6.15, the different types of available materials are discussed.

6.15.1 Well Screen and Casing Materials

A. When selecting the materials for well construction, the prime concern is to select materials that will not contribute foreign constituents, remove constituents of concern from the ground water, are compatible with the constituents of concern, and will not react with the constituents of concern. If the monitoring program calls for the analyses of only inorganic compounds or the contaminants or formation are highly corrosive, then rigid PVC materials, meeting National Sanitary Foundation (NSF) Standard 14 type Well Casing (WC), are acceptable. PVC materials may be acceptable for monitoring identified organic compounds in a soluble aqueous phase where incompatibilities are known to not exist. EPA document EPA/540/S-95/503, Nonaqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling, and Remediation, will be used for guidance in this area and in the use of PVC with non-aqueous phase liquids (NAPLs). Another concern is to select materials that will be rugged enough to endure the entire monitoring period. Site conditions will generally dictate the type of materials that can be used. A preliminary field investigation will be conducted to determine the geologic conditions, so that the most suitable materials can be selected. The best grade or highest quality material for that particular application is to be selected. Each manufacturer can supply the qualitative data for each grade of material that is being considered. All materials selected for MW installation are to be evaluated and approved by a lead field geologist prior to field activities.

B. Well screen and casing materials, generally used in MW construction on RCRA and Superfund sites, are listed in order of preference:

   1. Stainless Steel (304 or 316)

   2. Rigid PVC meeting NSF Standard 14 (type WC)

   3. Other (where applicable)

C. In cases where a driven-casing is used, or a high-strength outer casing is needed, carbon steel may be acceptable in non-corrosive aquifers. This outer casing is to have threaded connections. Welding casing is not an acceptable practice unless all relevant safety issues have been adequately addressed.

6.15.1 Well Screen and Casing Materials (continued)

D. The minimum nominal casing size for most permanent MWs will be two inches. Where a complete program of installation, monitoring, and abandonment is being designed, smaller wells may be installed, if suitable purging and sampling equipment for the smaller diameter wells can be specified and obtained. The length of well screens in permanent MWs are to be long enough to effectively monitor the interval or zone of interest. However, well screens designed for long-term monitoring purposes will normally not be less than five feet in length. Well screens less than five feet long are generally only used in temporary MWs where ground water samples are collected for screening purposes.

6.15.2 Filter Pack Materials

The filter pack materials are to consist of clean rounded to well-rounded, hard, insoluble particles of siliceous composition. The required grain-size distribution or particle sizes of the filter pack materials is to be selected based upon a sieve analysis conducted on the soil samples collected from the aquifer materials and/or the formation(s) to be monitored. Filter pack materials will not be accepted unless proper documentation can be furnished as to the composition, grain-size distribution, cleaning procedure, and chemical analysis. If a data search or previous site investigations reveal that there is enough existing data to adequately design the well screen and filter pack, then it may not be necessary to conduct a sieve analysis on the formation materials to be monitored. However, all data and design proposals will be evaluated and approved by a lead field geologist before field activities begin.

6.15.3 Filter Pack and Well Screen Design

A. The majority of MWs are installed in shallow ground water aquifers that consist of silts, clays, and sands in various combinations. These shallow aquifers are not generally characteristic of aquifers used for drinking water. Therefore, modifications to the procedures, used for the design of water well filter packs, may be required. In cases where insufficient experience exists with local or similar materials, the filter pack and well screen design is to be based on the results of a sieve analysis conducted on soil samples collected from the aquifer or the formation(s) that will be monitored.

B. In formations consisting primarily of fines (silts and clays), the procedures for water well screen design may result in requirements for filter packs and screen slot sizes that are not available. In those cases, the selection of 0.010-inch screen slots with a 20-40 sand filter pack, or 0.005-inch screen slots with 100 sand filter pack for very fine formations, will be acceptable practice. Table 1, Sand Pack Specifications, provides size specifications for the selection of sand packs for fine formation materials. ASTM Standard D5092, Design and Installation of Ground Water Monitoring Wells in Aquifers, may be consulted for further guidance on specifications for sand appropriate for these applications.

6.15.3 Filter Pack and Well Screen Design (continued)

Screen Opening (inch)	Sand Pack Mesh Name	1% Passing Size (d-1) (inch)	10% Passing Size (d-10) (inch)	30% Passing Size (d-30) (inch)	Derived 60% Passing Size (d-60) (inch)	Range for Uniformity Coefficient
0.005-0.006	100	0.0035-0.0047	0.0055-0.0067	0.0067-0.0083	0.0085-0.0134	1.3-2.0
0.010	20-40	0.00998-0.0138	0.0157-0.0197	0.0197-0.0236	0.020-0.0315	1.1-1.6

Table 1, Sand Pack Specifications

C. Section 6.15.3C is used in coarser grained formations:

1. The data from the sieve analysis are plotted on a grain-size distribution graph, and a grain-size distribution curve is generated. From this grain-size distribution curve, the uniformity coefficient (Cu) of the aquifer material is determined. The Cu is the ratio of the 60 percent finer material (d60) to the 10 percent finer material (d10).

2. Cu = (d60/d10)

   The Cu ratio is a way of grading or rating the uniformity of grain size. As a general rule, to ensure that individual grain sizes of the material are of similar particle size, a Cu of 2.5 or less, is to be used in designing the filter pack and well screen.

3. Before designing the filter pack and well screen, the following factors are to be considered:

   a. Select the well screen slot openings that will retain 90 percent of the filter pack material.

   b. The filter pack material is to be of the size that minimizes head losses through the pack and also prevents excessive sediment (sand, silt, clay) movement into the well.

   c. A filter material of varying grain sizes is not acceptable because the smaller particles fill the spaces between the larger particles, thereby reducing the void spaces and increasing resistance to flow. Therefore, filter material of the same grain size and well-rounded is preferred.

   d. The filter pack design is based on the gradation of the finest aquifer materials being analyzed.

6.15.3 Filter Pack and Well Screen Design (continued)

D. Section 6.15.3D is used to design a filter pack in aquifiers:

1. Construct a grain-size distribution curve, on a grain-size distribution graph, from the sieve analysis of the aquifer materials. The filter pack design is based on the gradation of the finest aquifer materials.

2. Multiply the d30 size from the grain-size distribution graph by a factor of four to nine (Pack-Aquifer ratio). A factor of four is used if the formation is fine-grained and uniform (Cu is less than three), six if it is coarse-grained and non-uniform, and up to nine if it is highly non-uniform and contains silt. Head losses through filter packs increase as the Pack-Aquifer (P-A) ratios decrease. In order to design a fairly stable filter pack with a minimum head loss, the d30 size is to be multiplied by a factor of four.

3. Plot the point from step 2 on the d30 abscissa of a grain-size distribution graph and draw a smooth curve with a uniformity coefficient of approximately 2.5.

4. A curve for the permissible limits of the filter pack is drawn, plus or minus eight percent of the desired curve with the Cu of 2.5.

5. Select the slot openings for the well screen that will retain 90 percent, or more, of the filter pack material.

6. The lead field geologist and/or engineers are to be responsible for the correct design of the MWs.

6.16 Groundwater Monitoring Well Development

A. A newly completed MW shall not be developed for at least 24 hours after the surface pad and outer protective casing are installed. This will allow sufficient time for the well materials to cure before development procedures are initiated. The benefits of developing new MWs are to remove the residual materials remaining in the wells after installation has been completed, and to re-establish the natural hydraulic flow conditions of the formations which may have been disturbed by well construction. A new MW is to be developed until the column of water in the well is free of visible sediment, and the pH, temperature, turbidity, and specific conductivity have stabilized. In most cases the above requirements can be satisfied; however, in some cases the pH, temperature, and specific conductivity may stabilize, but the water remains turbid. In this case, the well may still contain well construction materials, such as drilling mud in the form of a mud cake and/or formation soils that have not been washed out of the borehole. Excessive or thick drilling mud cannot be flushed out of a borehole with one or two well volumes of flushing. Continuous flushing over a period of several days may be necessary to complete the well development. If the well is pumped to dryness, or near dryness, the water table will be allowed to sufficiently recover to the static water level before the next development period is initiated. Caution is to be taken when using high-rate pumps and/or large-volume air compressors during well development because excessive high rate pumping and high air pressures can damage or destroy the well screen and filter pack. The lead field geologist will make the decision as to the development completion of each well. All field decisions are to be documented in the field log book, as specified by ENV-TI-05.80.03, Field Record Keeping.

B. The following development procedures, listed in approximate increasing order of the energy applied to the formation materials, are generally used to develop, or redevelop wells:

1. Bailing
2. Pumping/over-pumping
3. Surging
4. Backwashing (rawhiding)
5. Jetting
6. Compressed air, with appropriate filtering: airlift pumping and air surging

6.16 Groundwater Monitoring Well Development (continued)

C. These development procedures can be used, individually or in combination, in order to achieve the most effective well development. In most cases, over-pumping and surging will adequately develop the well without imparting undue forces on the formation or well materials. Because of the danger of introducing contaminants with the airstream, the possibility of entraining air in the aquifer, and the violent forces imparted to the formation, air surging is the least desired method of development and is to only be used where there is a specific need for the procedure. Air-lift pumping is permissible where an eductor pipe is used and several well volumes of water are removed from the well by other pumping means after air-lift pumping. The selected development method(s) are approved by a lead field geologist and recorded in the field logbook before any well development activities are initiated.

D. Section 6.16D is used for groundwater MW development:

1. Develop the groundwater MWs after the grout seal has properly cured, as determined by the Field Team Leader. A minimum of a 24-hour waiting period is required prior to development.

2. Develop the MW until the formation water discharged from the well is as clean and free of sand and fines, as is practical, to ensure that the well provides representative aquifer samples.

3. Determine when to terminate development, based on the well reaching steady state conditions, as measured by the following criteria:

   a. pH = +/- 0.1 SU

   b. Temperature and specific conductivity = +/- 10%

   c. Appearance (opaque, transparent, or clear)

   d. Flow rate (maximum stabilized flow rate attained)

   e. Turbidity less than 5 NTUs

4. Develop the MWs using surge-block techniques, purging with air, purging with a pump, or a combination of these techniques.

5. If a MW cannot be cleaned of fines to produce formation water because the aquifer yields insufficient water, inject small amounts of potable water to clean up the poorly yielding well. Do not add water to assist MW development without the approval of the TVA Project Manager.

6. Record the volume and source of potable water in the field logbook.

6.16 Groundwater Monitoring Well Development (continued)

7. During development, maintain the following information in the field logbook:
    a. Development time
    b. Development method
    c. Rate and volume of discharge water
    d. Temperature, pH, turbidity, and specific conductance of discharge water
    e. DTW-level readings before, during, and after well development
8. Estimated well yield PZs do not require development.
9. Effective well development requires movement of water in both directions through screen openings (or water-producing bedrock fractures). Reverse flow helps to reduce bridging of sand and fines.

6.16.1 Over-Pumping

A. A surface, or submersible, pump is used to develop the well by the over-pumping method.

B. To verify proper development by this method, initially set the pump intake at the bottom of the well and then move toward the top of the borehole or screen as development proceeds.

C. This method is most effective when used in conjunction with the surge-block development technique.

6.16.2 Surge-Block Techniques

Surge block techniques force fluids into the formation as the surge block is lowered, or pushed, down the borehole. The upstroke motion creates a suction that loosens the fluids and pulls loose sediment from the formation into the well.

A. Purge the well as often as possible between surging to remove loose sediment.

B. If applicable, measure the drawdown in nearby well(s) during development to characterize the interconnections of the wells.

6.16.3 Sampling Pump Calibration

A. Dedicated sampling pumps may be calibrated, when installed, in order to facilitate purging prior to sample collection. Prior to energizing the dedicated pump, measure the initial depth-to-water level, as specified by ENV-TI-05.80.44, Groundwater Level and Well-Depth Measurement, using a clean, properly decontaminated water-level indicator (and interface probe, if applicable).

B. Lower the electronic water-level probe into the well until the probe contacts the groundwater. Allow sufficient time for the static groundwater level to equilibrate with atmospheric pressure. Once the water level has reached equilibrium, record the initial water level.

C. Begin purging the well at the minimum pumping rate of 0.1 liter per minute (L/min). Slowly increase the pumping rate to a level that does not cause the well to draw down more than about 0.3 feet (10 cm), if possible. Never increase the pumping rate to a level in excess of 0.5 L/min (approximately 0.13 gallon per minute [gpm]). If the minimal drawdown that can be achieved exceeds 0.3 feet, but remains stable, continue the purging (US EPA, 2017).

D. Record stabilized flow rate, drawdown, and time.

E. Monitor and record the pump rate using a graduated cylinder or other measuring device periodically throughout the pump calibration activities. Record fluctuations of pump rate and subsequent adjustments

NOTE

For wells that have very slow recharge rates or that drawdown excessively at the minimum pumping rate of 0.1 L/min or 0.026 gpm, the procedures described below may not apply. For these wells, the Field Team Leas shall seek guidance from the appropriate TVA personnel about the appropriate purging and sampling methodologies to be employed.

F. Once an acceptable drawdown has been established and maintained, begin monitoring the designated indicator field parameters. The initial and periodic calibration checks of the meter(s) used to measure the indicator parameters are to be performed and documented, in accordance with ENV-TI-05.80.46, Field Measurement Using a Multi-parameter Sonde. These indicator parameters include pH, specific conductance, and turbidity. The water level in the well is to be measured to monitor drawdown during purging activities.

G. Indicator parameters are deemed stabilized when three consecutive readings, taken at three- to five-minute intervals, meet the criteria (US EPA, 2017) in Table 2, Indicator Parameters:

6.16.3 Sampling Pump Calibration (continued)

Turbidity	Below 5 NTUs or ± 10% for values above 5 NTUs and stable
pH	± 0.1 standard pH unit
Specific Conductance	± 3% in μS/cm
DO	Below 0.5 mg/L or ± 10% for values greater than 0.5 mg/L

Table 2, Indicator Parameters

H. The target for turbidity is readings less than or equal to 5 NTUs, but this value may not be achievable in some instances. Turbidity levels may exceed the desired turbidity level due to natural aquifer conditions (US EPA, 2017). When these conditions are encountered, purging will continue until turbidity has stabilized, even if that is at a level above 5 NTUs.

I. If critical indicator field parameters have not stabilized after two hours of documented purging, discontinue purging. Fully document efforts used to stabilize the parameters, such as modified pumping rates, and notify the appropriate TVA personnel.

J. Where turbidity is greater than 5 NTUs, the integrity of the monitoring well may be inspected using a downhole video camera. The video inspection will include documentation of the condition of the well screen and well casing above the screen.

NOTE

When flooding occurs triggering a re-development event a comparison of the mock-purge stabilization values to historic groundwater stabilization data is to be performed to evaluate whether the aquifer has returned to equilibrium. In some cases this evaluation may show that the minimum timeframe between redevelopment and sampling shown above is not adequate and additional time may be required. Provide historical and mock purge stabilization data to the TVA Groundwater Program Manager with a request for a determination of whether additional aquifer equilibration time is required prior to sampling.

K. After development is completed, wells should be allowed to stabilize and re-equilibrate before sampling. The time necessary for stabilization depends on the characteristics of the aquifer and the geochemistry of the parameters to be monitored. Generally, high permeability formations require less time (i.e.; several days) than low permeability formations (i.e.; several weeks) (US EPA, 2013).

6.16.3 Sampling Pump Calibration (continued)

1. Wells developed with stressful measures may require as long as a seven-day interval before sampling. In particular, air surge developed wells require 48 hours, or longer, after development so that the formation can dispel the compressed air and re stabilize to pre well development conditions.

2. Wells developed with surging and overpumping require different equilibration times depending upon their geologic setting as defined in the table below:

TVA Plant Site	Time Required between Redevelopment and Sample Collection
ALF	48 Hours between re-development and purging for sample collection
BRF	1 Week between re-development and purging for sample collection
COF	1 Week between re-development and purging for sample collection
CUF	1 Week between re-development and purging for sample collection
JSF	1 Week between re-development and purging for sample collection
JOF	48 Hours between re-development and purging for sample collection
KIF	1 Week between re-development and purging for sample collection
PAF	48 Hours between re-development and purging for sample collection
SHF	48 Hours between re-development and purging for sample collection

L. When flooding occurs, triggering a re-development event, a comparison of the mock-purge stabilization values to historic groundwater stabilization data is to be performed to evaluate whether the aquifer has returned to equilibrium. In some cases this evaluation may show that the minimum timeframe between redevelopment and sampling shown above is not adequate and additional time may be required. Provide historical and mock purge stabilization data to the TVA Groundwater Program Manager with a request for a determination of whether additional aquifer equilibration time is required prior to sampling.

6.17 Field Logbook Documentation

A. Information associated with monitoring well inspection and maintenance is to be recorded in field logbooks, inspection checklists, and maintenance records as well as electronic data collection systems. Field work must be properly documented. Depending on the requirements of your organization, there are different mechanisms for recording. You must meet the requirements for your specific organization.

1. Electronic data collection system
2. Field logbooks
3. Field worksheets
4. Field notebooks
5. Data sheets

B. Field logbooks to record daily activities, including boring logs and well construction diagrams, are maintained by the Field Team Leader, or designee. Entries are recorded in indelible ink. In addition to the minimum requirements discussed in TVA-ENV-TI-05.80.03, Field Record Keeping, the field logbooks document field activities specific to this TI and as defined in the applicable project work control documents. A location map, or site sketch locating the well or boring in relation to other onsite features, is recorded in the field logbook.

C. The Field Team Leader, and/or designee, are to review the field logbook entries on a weekly basis during installation activities for completeness and accuracy and document this review by initialing the entries. The Field Team Leader, or designee, is also responsible for the completion of required data collection forms.

6.18 Boring Log and Well Construction Diagram

A boring log and well construction diagram is completed for each boring and well installation conducted. An example of the boring log form, Attachment 2, Example - Boring Log, and MW installation field log form, Attachment 3, Example - Monitoring Well Installation Field Log, are attached. These forms are necessary to provide consistent and detailed information for use in project evaluation and documentation. Depth measurements are to be taken from the ground surface and recorded, as such. The information listed below, at a minimum, is recorded on the boring log.

6.18 Boring Log and Well Construction Diagram (continued)

A. General Site Information

1. Facility name where the borings are located
2. Well and/or boring number consistently referenced throughout reports and plans
3. Start and completion date and time
4. Name of the individual logging the well and/or boring
5. Driller's name and name of drilling company
6. Drilling method
7. Drill make and model

B. Boring Log Information

1. Water Level - water level first encountered and at completion of the well
2. Penetration Rate - blow count, min/ft, etc.
3. Depth in feet below ground level
4. Interval and recovery
5. Organic vapor detector readings, if necessary
6. Location and analysis of samples collected
7. Classification of Soils via Burmeister or USCS, which include, but are not limited to the following:
    a. Rock Type/Soil Type - primary and secondary lithologies
    b. Composition/Texture - size and shape of the particles
    c. Strength/consistency
    d. Color
    e. Moisture
    f. Bore hole direction
    g. Overburden thickness

6.18 Boring Log and Well Construction Diagram (continued)

        h. Depth drilled into rock

        i. Total depth of borehole

        j. Weathering observations

C. Well Completion Information

1. Completion Diagram - detailed MW schematic, which indicates, but is not limited to, the following:

    a. Borehole diameter and depth

    b. Type, diameter, and depth of well

    c. Type and length of casing and screen

    d. Slotted screen size

    e. Grain size of sand pack

    f. Depth to top of screen, sand pack, and bentonite seal

    g. Depth to water reading after installation

    h. Grout information - manufacturer, slurry mixture/ratios, volume used, etc.

    i. Bentonite seal depth thickness: manufacturer of bentonite and form (granulated or pellets), volume used, etc.

    j. Geologic conditions: overburden, bedrock, etc.

2. Top of well casing in mean sea level (MSL) elevation in feet. Elevation measurements are determined by a Professional Land Surveyor (PLS) following completion of the MW.

3. Top of screen, bottom of screen, and bottom of well in feet below ground surface.

6.19 Decontamination and Waste Management

Equipment used for well installation and development are decontaminated in a manner consistent with the TVA-ENV-TI-05.80.05, Field Sampling Equipment Cleaning.

6.20 Investigation-Derived Waste

A. IDW includes excess samples, cuttings, decontamination fluids, disposable sampling equipment, and disposable personal protective equipment (PPE). IDW is containerized according to requirements in Table 3, Investigation-Derived Waste, or in accordance with the facility specific SAP. The work area is disassembled and, to the extent practical, returned to its original condition.

B. IDWs, such as PPE, waste media, and decontamination fluids will be managed in accordance with Table 3, Investigation-Derived Waste. Coordinate with appropriate facility personnel to arrange for disposal of IDW based on results of analytical data, or in accordance with the facility-specific waste management plan.

Investigation-Derived Waste Stream	Disposition Pathway
General refuse (such as paper, plastic bags, and cardboard)	Dispose as municipal trash or recycle, as appropriate.
PPE (such as nitrile and latex gloves)	Dispose as municipal trash for routine activities.
Decontamination fluids, auger cuttings, and waste waters	Containerize in appropriate containers dependent on user’s knowledge, and dispose appropriately based on analytical results. CCR decontamination fluids as mentioned in 6.11 may not need to be containerized.

Table 3, Investigation-Derived Waste

7.0 RECORDS

Records generated in the process of performing the activities in this TI must be processed and maintained as stated in the Environmental Records Matrix, in accordance with the TVA Document Services Records Management procedures.

7.1 Quality Assurance Records

A. Field logbooks and data sheets

B. Boring logs

C. Well construction diagrams

7.2 Non-Quality Assurance Records

None

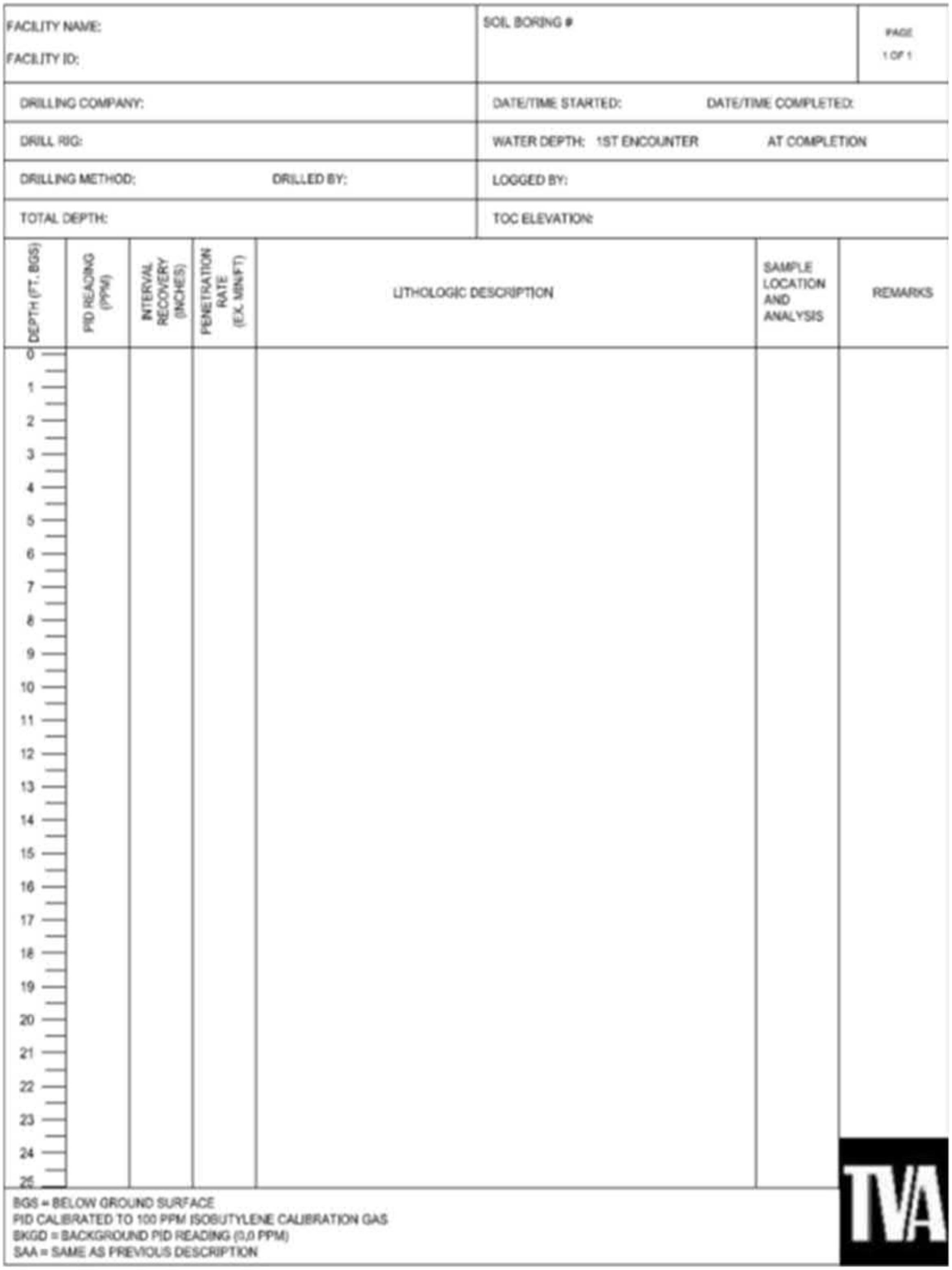
Attachment 1
(Page 1 of 1)

Recommended Well Depth Measurement Equipment and Materials Checklist

Item Description	Check
Health & Safety	
Hearing protection	
Non-powdered nitrile or latex gloves	
Field first-aid kit and eyewash	
Hard hat and steel-toed boots	
Safety goggles	
Reflective safety vest	
Paperwork	
JSA and PJB	
Project work and sampling planning documents	
Field logbook or data sheets	
Boring logs	
Well construction diagrams	
Well Depth Measurement Equipment and Materials	
Water level meter	
Oil / water interface meter	
Replacement batteries	
DI water	
Invar® steel surveyor’s chain (if calibrating meter)	
Decontamination solutions and waste management supplies	

Attachment 2
(Page 1 of 1)

Example - Boring Log



FACILITY NAME:
FACILITY ID:
SOIL BORING #
PAGE 1 OF 1

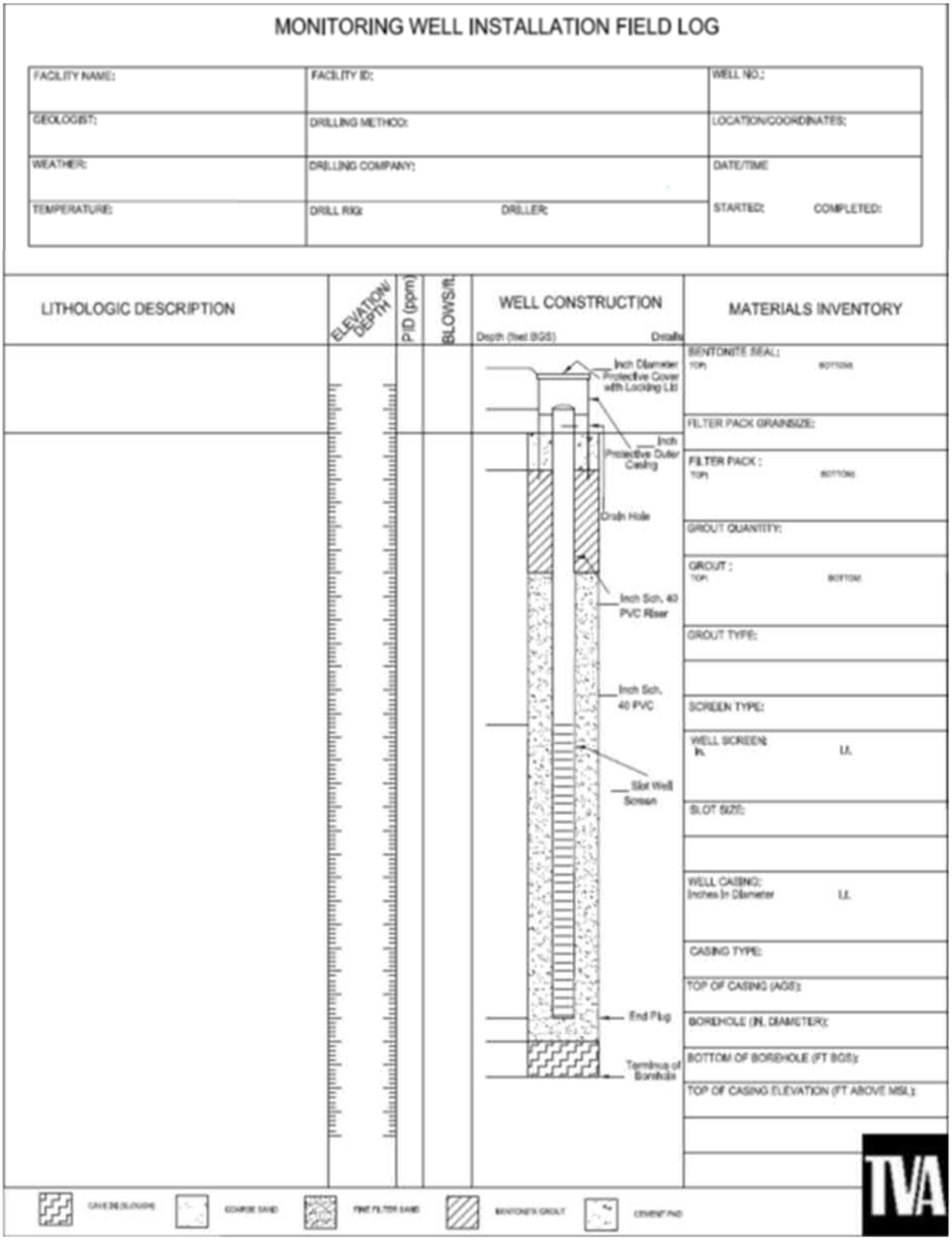
DRILLING COMPANY:
DATE/TIME STARTED:
DATE/TIME COMPLETED:
DRILL RIG:
WATER DEPTH: 1ST ENCOUNTER
AT COMPLETION
DRILLING METHOD:
DRILLED BY:
LOGGED BY:
TOTAL DEPTH:
TOC ELEVATION:

DEPTH (FT. BGS)	PID READING (PPM)	INTERVAL RECOVERY (INCHES)	PENETRATION RATE (EX. MIN/FT)	LITHOLOGIC DESCRIPTION	SAMPLE LOCATION AND ANALYSIS	REMARKS
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						

BGS = BELOW GROUND SURFACE
PID CALIBRATED TO 100 PPM ISOBUTYLENE CALIBRATION GAS
BKGD = BACKGROUND PID READING (0.0 PPM)
SAA = SAME AS PREVIOUS DESCRIPTION

Attachment 3
(Page 1 of 1)

Example - Monitoring Well Installation Field Log



MONITORING WELL INSTALLATION FIELD LOG

FACILITY NAME:	FACILITY ID:	WELL NO.:
GEOLOGIST:	DRILLING METHOD:	LOCATION/COORDINATES:
WEATHER:	DRILLING COMPANY:	DATE/TIME
TEMPERATURE:	DRILL RIG: DRILLER:	STARTED: COMPLETED:

LITHOLOGIC DESCRIPTION	ELEVATION/ DEPTH	PID (ppm)	BLOWS/ft.	WELL CONSTRUCTION Depth (feet BGS) Details	MATERIALS INVENTORY

MATERIALS INVENTORY

BENTONITE SEAL:
TOP: BOTTOM:

FILTER PACK GRAINSIZE:

FILTER PACK:
TOP: BOTTOM:

GROUT QUANTITY:

GROUT:
TOP: BOTTOM:

GROUT TYPE:

SCREEN TYPE:

WELL SCREEN:
In. Lf.

SLOT SIZE:

WELL CASING:
Inches In Diameter Lf.

CASING TYPE:

TOP OF CASING (AGS):

BOREHOLE (IN. DIAMETER):

BOTTOM OF BOREHOLE (FT BGS):

TOP OF CASING ELEVATION (FT ABOVE MSL):

CAVE IN (SLOUGH) COARSE SAND FINE FILTER SAND BENTONITE GROUT CEMENT PAD

Environmental Compliance and Operations

Technical Instruction

ENV-TI-05.80.42

Groundwater Sampling

Revision 0003

Level of Use: Reference Use

Effective Date: 09-16-2019

Responsible Organization: Environmental Compliance and Operations

Prepared by: Environmental Compliance and Operations

Reviewed by: Donald W. Snodgrass Date: 08-27-2019

Reviewed by: James Osborne Date: 08-28-2019

Concurred by: Brian S. Fowler Date: 08-28-2019

Approved by: M. Susan Smelley Date: 09-09-2019

Revision Log

Revision or Change Number	Effective Date	Affected Page Numbers	Description of Revision/Change
0001	03/31/2017	All	Align with other environmental TIs and to incorporate specifics on Coal Combustion Residual (CCR) compliance activities.
0002	7/14/17	All	Includes section on sampling well pump calibration; Adds wording in General Consideration section on recording requirements in order to reduce redundant wording throughout the document.
0003	9/16/19	All	Changes made throughout document.

Table of Contents

Table of Contents (continued)

1.0 PURPOSE

This Technical Instruction (TI) provides the general technical requirements and operational guidelines for collecting groundwater samples from monitoring wells for field screening or laboratory analysis.

2.0 SCOPE

A. This TI applies to TVA field sampling personnel and TVA contractors who collect routine groundwater samples for TVA's regional groundwater management program, for the assessment of groundwater quality, and for various regulatory and operational purposes.

B. This document is applicable to groundwater sampling, using bailers, and low-flow pumps.

C. This TI does not include detailed procedures for collecting water for chemical analysis of volatile organic compounds or for low-level mercury analysis. These are detailed in ENV-TI-05.80.43, Water Sampling for Volatile Organic Compounds Analysis, and ENV-TI-05.80.68, Low-Level Mercury Sampling. Refer to these TIs when sampling for the respective parameter(s).

D. Groundwater sampling guidance can be found in the Environmental Protection Agency (EPA) Region 4, SESDPROC-301, Groundwater Sampling Operating Procedure, and Region 1, Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells.

Review Cadence: This TI will be reviewed every four years, with the review documented in the Revision Log.

3.0 PRECAUTIONS/LIMITATIONS

3.1 Precautions

None

3.2 Limitations

None

4.0 REFERENCES

4.1 Performance References

A. Code of Federal Regulations (CFR), 40 CFR Part 136, Guidelines Establishing Test Procedures for the Analysis of Pollutants, including all Method Update Rules (MURs)

B. ENV-TI-05.80.01, Planning Sampling Events

C. ENV-TI-05.80.02, Sample Labeling and Custody

D. ENV-TI-05.80.03, Field Record Keeping

E. ENV-TI-05.80.04, Field Sampling Quality Control

F. ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination

G. ENV-TI-05.80.06, Handling and Shipping of Samples

H. ENV-TI-05-80.21, Monitoring Well Inspection and Maintenance

I. ENV-TI-05.80.43, Water Sampling for Volatile Organic Compounds Analysis

J. ENV-TI-05.80.44, Groundwater Level and Well-Depth Measurement

K. US EPA, Region 1, EQASOP-GW4, Revision 4, Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells, 2017

L. US EPA, Region 4, SESDPROC-301-R4, Groundwater Sampling Operating Procedure, 2017

M. TVA-SPP-18.005, Plan Jobs Safely

4.2 Developmental References

A. American Public Health Association, Water Works Association, and Water Environment Federation, variously dated, Standard Methods for the Examination of Water and Wastewater (SMWW), 23rd Edition, Washington, DC, 2011

B. ENV-TI-05.80.40, Surface Water Sampling

4.2 Developmental References (continued)

C. EPA, Office of Research and Development, Office of Solid Waste and Emergency Response. Ground Water Issue, Low-Flow (Minimal Drawdown Sampling Procedures), Document Number EPA/540/S-95/504," April 1996

D. US Geological Survey (USGS), National Field Manual for the Collection of Water-Quality Data: Techniques of Water-Resources Investigations, Book 9, Handbooks for Water-Resources Investigations

4.3 Commitments

None

5.0 PREREQUISITE ACTIONS

None

6.0 PERFORMANCE

6.1 General Considerations

A. Field personnel conducting groundwater sampling are required to be familiar with the procedures in this TI, as well as standard industry practices.

B. Field work must be properly documented. Depending on the requirements of the organization, there are different mechanisms for recording. The field personnel must meet the requirements for the specific organization.

1. Groundwater Application, or other electronic data collection system
2. Field logbooks
3. Field worksheets (see Attachment 1, Example - Preliminary Groundwater Data Field Worksheet)
4. Field notebooks
5. Data sheets

C. Potential hazards associated with the planned groundwater sampling activities are to be thoroughly evaluated prior to conducting field activities. During planning and sampling activities, procedures to ensure safety will be incorporated according to the TVA Standard Programs and Processes (SPP), TVA-SPP-18.005, Plan Jobs Safely, which provides information on using job safety analyses (JSAs) and pre-job briefings (PJB).

6.1 General Considerations (continued)

D. Great care must be taken to avoid and prevent sample contamination. Sampling personnel must wear powder-free nitrile or latex gloves, as appropriate, while preparing sample containers, preparing and decontaminating sampling equipment, and at all times while collecting and packing samples. At a minimum, gloves must be changed prior to the collection of each sample, or, as necessary, to prevent the possibility of cross-contamination with the sample, the sample containers, and/or the sampling equipment. Other type polymer gloves may be used when not sampling for organic analytes, provided they are powder-free. Samples should not be allowed to contact gloves and flow into the sample container. Gloves should be changed any time during sample collection when their cleanliness is suspected or demonstrated to have been compromised.

E. Sample bottles will be received pre-preserved when procured from the laboratory for groundwater analysis.

F. Any buckets, coolers, or bags used to hold the samples or sample bottles should be clean and free from debris.

6.2 Pre-Field Sampling Preparation

Prior to leaving for the collection site, the Field Team Lead is responsible for ensuring that the following activities have been completed:

A. Prepare, or obtain and review, a sampling diagram, chart, or plan, such as a facility-specific Sampling and Analysis Plan (SAP) or Quality Assurance Project Plan (QAPP), that designates the monitoring wells to be sampled and their location, the number of samples to be collected, a list of the analytical requirements for each sampling location, and number of quality control (QC) samples needed. Refer to ENV-TI-05.80.01, Planning Sampling Events. QC samples may include, but are not limited to, rinsate/filter/equipment blanks, laboratory blanks, field blanks, field duplicate samples, and matrix spike/matrix spike duplicate samples. Refer to ENV-TI-05.80.04, Field Sampling Quality Control. Identify tools, instruments, sample containers, preservatives, quantity of ice, number of coolers, relevant logbooks, worksheets, custody paperwork, and other items needed for the groundwater sampling event.

B. Review Job Safety Analysis (JSA) Worksheet – Form 15943 and identify needed safety equipment. Conduct a Pre-Job meeting prior to beginning work and document on the Pre-Job Brief Checklist – Form 40898. Once the work activities are complete conduct a post-job meeting and document the meeting using the Post-Job Review Checklist - Form 40899.

6.2 Pre-Field Sampling Preparation (continued)

C. If available, review boring logs, well construction details, and survey data that identify the documented point of reference (benchmark) for collection of depth-to-groundwater, as well as total well-depth information, previous depth-to-groundwater measurements, previous pump placement depths for each sampling location, previous pump settings and pumping and drawdown rates, and previous analytical results for each monitoring well.

D. Obtain equipment necessary for completing the groundwater sampling. See Attachment 2, Example - Groundwater Sampling Equipment and Materials Checklist, for an example checklist of equipment and materials, including site-specific maps or Global Positioning System (GPS) coordinates showing clearly marked monitoring well locations or groundwater sample points. It is important to note that the items on the checklist are not intended to be all-inclusive and the preparation of an event-specific checklist of equipment and materials is highly recommended.

E. Obtain potable and deionized (DI) water for decontamination. Record the water source. Laboratory supplied DI water is to be used for collection of all field blanks and rinsate blanks. Ensure and document that all sampling equipment has been cleaned, in accordance with ENV-TI-05.80.05, Field Equipment Cleaning and Decontamination.

F. Verify that legal right-of-entry has been obtained and site access has been granted, where required. Notice of planned sampling events should be provided to the property owner and/or appropriate plant personnel. Pre-identify any potential site access logistical issues and take actions to address them.

6.3 Water-Level Measurements (Well Preparation)

A. All water levels at a given site should be obtained within a 24-hour period. An independent round of water levels could be measured at the beginning of the sampling event, in addition to water levels at each well at the time of sampling.

B. In the event of a moderate to heavy rainfall, stop measuring water levels and consult with a Waste Specialist or TVA Project Manager to determine length of time needed for water levels to equilibrate. All water levels may need to be measured again.

C. Approach the monitoring well with caution, particularly in warm weather, watching for snakes, fire ants, wasp nests (may be inside well cover), and other hazards. Do not use poisons/chemicals that may affect the quality of the sample at the well head.

6.3 Water-Level Measurements (Well Preparation) (continued)

D. Inspect the wellhead area for evidence of damage or disturbance, in accordance with ENV-TI-05-80.21, Monitoring Well Inspection and Maintenance. Use the Monitoring Well Surface Inspection Checklist to record the visual inspection prior to beginning sampling. This form should be included with the sampling event field notes, either via Sharepoint or other inclusion with the Groundwater Application.

E. To minimize contamination of sampling equipment, place new plastic sheeting on the work surface at each sample location where sampling equipment or tubing may contact the ground surface around wells. A wind block or other configuration may be needed to maintain the plastic sheet in place.

F. Open the protective outer cover of the monitoring well. Remove any debris that has accumulated around the riser near the well plug. If water is present above the top of the riser and well plug, document this observation and remove the water prior to opening the well plug. Do not open the well until the water above the well head has been removed. When present, sealing well plugs should be left open for five minutes to allow the water level to equilibrate before measuring the water level.

G. For wells in which unknown levels of volatile organic vapors may be expected or if specified in the work planning documents, monitor and record the headspace in the well with a volatile organic compound (VOC) detector, equipped with a photoionization detector (PID), immediately after opening the well plug.

H. If the monitoring well has the potential to contain non-aqueous phase liquids (NAPLs) probe the well for these materials using an optical interface probe. If NAPLs are present, consult the Waste Specialist or TVA Project Manager for direction on collecting samples for analysis. In general, do not collect groundwater samples from monitoring wells containing NAPLs.

I. Prior to energizing the dedicated pump, or pump placement of non-dedicated pump, measure the initial depth-to-water level according to ENV-TI-05.80.44, Groundwater Level and Well-Depth Measurement, using a clean, properly decontaminated water-level indicator, and interface probe, if applicable.

J. For monitoring wells without dedicated pumps and screened across the water table, use this measurement to determine the required depth-to-pump intake (typically, mid-point of the saturated screen length for low-flow purging and sampling), unless otherwise directed by the TVA Waste Specialist or TVA Project Manager; record the measurement.

6.4 Well Purging

Wells must be purged prior to sampling to ensure that representative groundwater is obtained from the water-bearing unit. If the well has been previously sampled, in accordance with this TI, then the depth-to-pump intake and the pumping rates are to be duplicated to the maximum extent practical during subsequent sampling events; information is recorded. Section 6.4.1 provides a description of low-flow well purging, which is the preferred well purging and sampling method. Section 6.4.2 provides a description of purging, using disposable or dedicated, bailers. Section 6.4.3 provides a description of volume-averaged well purging. These sections are provided as a contingency in the event low-flow purging and sampling are not possible. Do not proceed with purging, using disposable bailers or volume-averaged purging, without TVA written approval.

6.4.1 Low-Flow Well Purging (Micro-Purging)

A. EPA guidance documents (EPA 1996) states that suction pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds. Accordingly, peristaltic pumps (suction) are not recommended for use in low-flow purging and sampling for dissolved gases and VOCs. Adjustable-rate bladder or centrifugal submersible pumps are preferred for use during low-flow purging and sampling activities. The low-flow purging and sampling technique is described in this section.

B. Measure and record the air temperature.

C. Using the specific details of well construction and current water-level measurement, determine the pump set depth (typically the mid-point of the saturated well screen or other target sample collection depth adjacent to specific high-yield zones). If the well has been previously sampled in accordance with this TI, then the depth-to-pump intake and the pumping rates should be duplicated to the extent practical, provided requirements for pump rates and drawdown are met. Energize and document that the dedicated pumps are at the previous settings.

6.4.1 Low-Flow Well Purging (Micro-Purging) (continued)

NOTE

If a portable pump is needed, the non-working dedicated pump must be removed prior to deployment of the new pump. If using new tubing, use new, certified clean, disposable Silastic®, Teflon®, Tygon®, or equivalent tubing, during well purging. If certified clean tubing is not available, collect a tubing blank for analysis, as specified in ENV-TI-05.80.04, Field Sampling Quality Control.

D. Lower the electronic water-level probe into the well until the probe contacts the groundwater. Allow sufficient time for the static groundwater level to equilibrate with atmospheric pressure. Once the water level has reached equilibrium, record the initial water level.

E. If it is necessary to deploy a non-dedicated pump (e.g.; due to dedicated pump malfunction), use the specific details of previous pump placement depth to determine the deployment depth of the new pump. Attach tubing and supporting line, such as rope, wire, or shrouded electrical cable bonded to sample tubing, to the pump and slowly lower the unit until the targeted pump intake depth is reached. Measure and record the length of supporting line required, taking into account the pump length, to attain the required depth. Record the depth-to-pump intake.

F. If the well has been previously samples, using low-flow purging and sampling methods, begin purging at the rate known to induce minimal drawdown. Frequently check the drawdown rate to verify that the maximum drawdown criteria are not being exceeded. Monitor the pump rate, using a graduated cylinder measuring device, periodically throughout the well purging activities, and record this check. Record fluctuations of pump rate and subsequent adjustments. Pumping rate measurements are to be performed, using the pump discharge tubing prior to connecting the flow-through cell to the pump discharge tubing. If results from the previous sampling event are not knows, begin purging the well at the minimum pumping rate of 0.1 liter per minute (L/min). Slowly increase the pumping rate to a level that does not cause the well to drawdown more than about 0.3 feet (10 cm), if possible. The pumping rate should not be increased to a level in excess of 0.5 L/min (approximately 0.13 gallon per minute [gpm]). If the minimal drawdown that can be achieved exceeds 0.3 feet, but remains stable, continue purging (US EPA, Region 1, 2017). Record stabilized flow rate, drawdown, and time.

6.4.1 Low-Flow Well Purging (Micro-Purging) (continued)

G. Connect the pump discharge to a flow-through cell equipped with a multi-parameter sonde for measurement of field parameters. The initial and periodic calibration checks of the meter(s) used to measure the indicator parameters are to be performed and documented, in accordance with ENV-TI-05.80.46, Field Measurement Using a Multi-Parameter Sonde. Turbidity is to be measured in a static sample collected from the discharge of the flow-through cell after other field parameter readings are taken. To minimize potential for cross-contamination of the outlet of dedicated turbing, a new, clean piece of connector tubing is to be used to bridge the dedicated sample tubing to the inlet of the flow-through cell.

NOTE

For wells that have very slow recharge rates or that drawdown excessively at the minimum pumping rate of 0.1 L/min or 0.026 gpm, the procedures described in this TI may not apply. For these wells, the Field Team Lead shall seek guidance from the Waste Specialist or TVA Project Manager about the appropriate purging and sampling methodologies to be employed, such as volume-averaged purging and sampling.

H. Once an acceptable drawdown has been established and maintained, begin monitoring designated indicator field parameters. The initial and periodic calibration checks of the meter(s) used to measure the indicator parameters are to be performed and documented, in accordance with ENV-TI-05.80.46, Field Measurement Using a Multi-Parameter Sonde. Indicator parameters include pH, oxidation-reduction potential (ORP measured as Eh), dissolved oxygen (DO), specific conductance, temperature, and turbidity. It is recommended that ORP and temperature are to be measured and recorded during micro-purging, but are not evaluated to determine stabilization, as described in Step 6.4.1H.1. The water level in the well is to be measured to monitor drawdown during purging activities. Base the frequency of the measurements on the time required to completely evacuate one volume of the flow through cell to ensure that independent and representative measurements are made. For example, a 500-mL cell in a system pumped at a rate of 100 mL/min is evacuated in five minutes. Measurements are to be recorded at three- to five-minute intervals at the time of measurement.

6.4.1 Low-Flow Well Purging (Micro-Purging) (continued)

1. Indicator parameters are deemed stabilized when three consecutive readings, taken at three- to five-minute intervals, meet the criteria in Table 1, Indicator Parameters, (US EPA, Region 1, 2017):

Turbidity	Below 5 NTUs or ± 10% for values above 5 NTUs and stable (refer to 6.4.1H.2)
pH	± 0.1 standard pH unit
Specific Conductance	± 3% in μS/cm
DO	Below 0.5 mg/L or ± 10% for values greater than 0.5 mg/L

Table 1, Indicator Parameters

2. The target for turbidity is readings less than or equal to 5 NTUs, but this value may not be achievable, and in some instances, turbidity levels may exceed the desired turbidity level due to natural aquifer conditions (US EPA, 1996). Turbidity measurements at the time of sample collection should be less than 5 NTUs for the collection of unfiltered samples. It is widely understood, however, that such a low threshold on the target turbidity value may not be achievable due to the strong presence of fine materials or other natural formation conditions. With the intent of collection, a sample with turbidity below 5 NTUs, the following scenarios will be followed, as applicable, provided the other parameters have met stabilization criteria:

   a. If turbidity is below 5 NTUs for three consecutive readings, purging will be deemed complete and sampling shall proceed.

   b. If turbidity is greater than 5 NTUs and is continuing to decrease, purging should continue for a total of up to 2 hours or until other conditions listed here are met. After two hours sampling will proceed.

   c. If turbidity is greater than 5 NTUs and there are three consecutive increasing turbidity measurements after decreasing values have been observed, sample collection will proceed.

   d. If turbidity is greater than 5 NTUs but is within plus or minus 10% of the previous reading for three consecutive readings, and historic purge logs for the well have shown that the well have consistently stabilized above 5 NTUs, purging will be deemed complete and sampling shall proceed.

6.4.1 Low-Flow Well Purging (Micro-Purging) (continued)

3. Where turbidity is greater than 5 NTUs, a second sample will be field-filtered (if sampling is Tennessee for TDEC) and submitted for dissolved metals analysis as detailed in Section 6.6.

NOTE

While every effort should be taken to ensure that indicator parameters stabilize, some indicator parameters are more critical with respect to certain contaminant types. It is important to identify which indicator parameters are most important to the project prior to commencement of field activities so that unnecessary protracted purge times can be avoided. For example, the critical indicator parameter associated with sampling for VOCs is DO, while the critical indicator parameter associated with metals is turbidity.

I. If critical indicator field parameters have not stabilized after two hours of documented purging, discontinue purging and collect samples, according to Section 6.5.1. Fully document efforts used to stabilize the parameters, such as modified pumping rates, and notify the Waste Specialist or TVA Project Manager, or customer.

NOTE

Direct sunlight and hot ambient air temperatures may cause the groundwater in the tubing and flow-through cell to heat up. This may cause the groundwater to degas, which will result in the loss of VOCs and dissolved gases. When purging and sampling under these conditions, the sampler will need to shade the equipment from the sunlight with a tent or umbrella (US EPA, Region 1, 2017).

J. There are a variety of water quality meters available that measure the water quality parameters identified in Step 6.4.1H.1. It is preferred, but not required, to utilize a water quality meter capable of measuring each of the water quality parameters, referenced in Step 6.4.1H.1 in one flow-through cell. If daily on-site calibration is recommended by the instrument manufacturer, the calibration procedures specified in the instruction manual shall be followed. ENV-TI-05.80.46, Field Measurement Using a Multi-Parameter Sonde, should also be reviewed. Calibration procedures shall be documented, including calibration solutions used, expiration date(s), lot numbers, and calibration results.

6.4.2 Purging Using a Bailer

A. Wells may be purged using a disposable polymer bailer, such as the Aqua Bailer (Aqua Bailers, Inc.) or equivalent (Teflon® bailers are required when collecting samples for organic analysis). Bailers can be disposable or dedicated. Bailers may be assigned to a single well, making them dedicated equipment. If bailers are dedicated to a single well, the bailers will be visually inspected for discoloration and the presence of foreign material prior to use. If discoloration or foreign debris is observed, replace with a new bailer.

B. Bailers may be used when water levels or volumes in a well are too low for the use of submersible pumps. Low-volume wells may be purged until dry or until three well volumes are removed. Bailers may be made of various materials, such as polyethylene or Teflon® contain check valves at the bottom, and may be weighted or non-weighted. As the bailer sinks in the water column, the check valve at the bottom allows water to fill the unit. As the bailer is withdrawn from the well, the weight of the water closes the check valve, thereby trapping water inside the bailer. The water in the bailer can either be poured out the top of the bailer or drained from the bottom, using a supplied hollow tip.

1. Select a new bailer sized to fit into well piping without binding on well casing.

2. Remove bailer from protective sleeve, while retaining the cover and removable drain tip.

3. Securely attach a new line (wire, cord, or rope) to the top of the bailer, ensuring that the line is of sufficient length for the bailer to reach the desired water level or the well bottom.

4. Lower the bailer into the well until the bailer contacts the surface of the water.

5. Allow the bailer to sink until the unit is filled with water. Avoid allowing the bailer to contact the well bottom.

6. It is critical that bailers be slowly and gently immersed into the top of the water column, particularly during the final stages of purging, to minimize turbidity and volatilization of volatile organic constituents.

7. Retrieve the bailer to the top of the well, while listening, to ensure the check valve is not leaking water back into the well. If the check valve is leaking, it may be necessary to bounce the unit up and down on the line to seal the valve.

8. Per site regulations, pour or drain the purge water into an appropriate waste container or onto the ground adjacent to the well.

6.4.2 Purging Using a Bailer (continued)

9. Track and record the volume of purge water removed from the well. Additionally, record specific information about the bailers used (manufacturer, material, size) and the total volume of purge water removed.

10. Once the purging process is complete, one or more additional full bailers will be collected from the well to measure and record field parameters. If the well has been purged dry, these measurements are to be made after the water level in the well has recovered sufficiently.

11. After sampling, secure or dispose of the bailer and line properly.

6.4.3 Volume-Averaged Well Purging

Volume-averaged sampling involves purging a specified volume of water, such as three to five well volumes, rather than basing purge completion on the stabilization of water quality indicator parameters. However, measuring and recording water-quality indicator parameters during purging provides information that can be used for assessment and remedial decision-making purposes. A minimum of three well volumes is purged from the well, using this method. Consult regulatory or site documents; e.g., SAP, QAPP, for total purge volume guidance.

A. Calculate the length of the standing water column in the well by subtracting the depth-to-water (DTW) from the total depth (TD) measurement. DTW and TD measurements shall be determined in accordance with ENV-TI-05.80.44, Groundwater Level and Well Depth Measurement.

B. Multiply the length of the standing water column by the volume calculation (liters per linear meter of depth) based on the inner casing diameter (see Table 2, Water Conversion) to determine the total standing water volume; this represents one well volume. The conversion factors in Table 2, correspond to well diameters commonly seen at TVA. If the diameter of a well is not in Table 2, consult industry practices to determine the proper conversion factor. Record these calculations.

6.4.3 Volume-Averaged Well Purging (continued)

Inner Well Casing Diameter (inch)	Volume Multiplier (L/linear meter)	Volume Multiplier (gallon per linear foot)
0.5	0.127	0.0102
2	2.024	0.163
3	4.560	0.367
4	8.110	0.653
5	12.67	1.020
6	18.24	1.469

Table 2, Water Conversion

C. Multiply the well volume calculated in Step 6.4.3B by three or five to obtain the respective total purge volume. The target purge volume is between three and five standing well volumes. For wells with multiple casing diameters, such as open bedrock holes, calculate the volume for each segment. Take the sum of the values and multiply by three and five to determine the minimum and maximum purge volumes, respectively.

D. Fully document the volume calculation.

E. Use a variable-speed electric submersible pump or, when purging shallow wells with small purge volumes, use of a disposable or dedicated bailer may be appropriate (refer to Section 6.4.2).

NOTE

If replacing tubing, use new, certified clean disposable Silastic®, Teflon®, or equivalent tubing during well purging.

F. Set the pump/hose assembly immediately above the top of the well screen or within the top of the water column (EPA 2013). The intake should not be lowered more than three to five feet within the water column for conventional purging (not applicable to micro purging).

G. Begin purging and monitor the water level. If the recovery rate of the well is faster than the pump rate and no observable drawdown occurs, the pump shall be raised until the intake is within one foot of the top of the water column. If the pump rate exceeds the recovery rate of the well, the pump will have to be lowered, as needed, to accommodate the drawdown (EPA 2013). Document pump depth adjustments.

6.4.3 Volume-Averaged Well Purging (continued)

H. Monitor the discharge rate, using a graduated cylinder or other measuring device, water-quality indicator parameters, if desired, and depth-to-water (DTW):

   1. Initially, within three minutes of startup

   2. On a periodic basis, such as every five minutes, or after each well volume is purged

   3. Immediately before purge completion

I. Record pump discharge rates (L/ min or gpm) and pump settings. Also, record any changes in the pump settings and the time at which the changes were made.

J. Maintain low pumping rates to avoid over-pumping or pumping the well to dryness, if possible. If necessary, adjust pumping rates, pump set depth, or extend pumping times to remove the desired volume of water.

NOTE

The removal of three to five well volumes may not be practical in wells with slow recovery rates. If a well is purged to near dryness, the well shall be allowed to completely recover prior to sampling. If necessary, the two-hour limit may be exceeded to allow for sufficient recovery, but samples must be collected within 24 hours of purge completion.

K. Upon reaching the desired purge water volume, proceed to Section 6.5 for collection of well samples.

6.5 Groundwater Sampling

6.5.1 Sampling after Low-Flow Purging

This section shall be followed for the collection of low-flow groundwater samples after completing purging, as defined in Section 6.4.1.

A. Arrange and label necessary sample bottles, and ensure that preservatives have been pre-added to the sample bottles, as required. Include a unique sample number, time and date of sampling, the initials of the sampler, and the requested analyses on the label. Additionally, record information pertinent to the preservation used in the sample. Consult the facility-specific SAP, QAPP, and ENV-TI-05.80.04, Field Sampling Quality Control, to determine the appropriate QC samples to be collected.

B. Record the final pump settings immediately prior to sample collection.

C. Measure and record the indicator parameter readings immediately prior to sample collection.

D. Record comments pertinent to the color and obvious odors, such as sulfur odor or petroleum hydrocarbons odor, associated with the water.

E. Do not change the flow rate used during purging for sample collection. Disconnect the pump sampling tubing (tubing extending out of the well that is connected directly to the well pump) from the flow-through cell, measure the pumping rate/flow rate and ensure it’s consistent with the flow rate used for stabilization and collect samples directly from the pump sampling tubing.

F. Ensure that the sampling tubing remains filled during sampling and that the water does not descend back into the well. Minimize turbulence when filling sample containers by allowing the liquid to run gently down the inside of each sample bottle. If project-specific documents (Work Plan, SAPs, etc.) do not specify a sample collection order, the labeled sample bottles should be filled in the following order:

    1. Volatile Organic Compounds (VOCs)
    2. Semi-volatile Organic Compounds (SVOCs)
    3. Pesticides/Polychlorinated Biphenlys (PCBs)
    4. Total Petroleum Hydrocarbons (TPH)
    5. Metals, Cyanide, and Radionuclides

6.5.1 Sampling after Low-Flow Purging (continued)

6. Filtered Metals and Radionuclides, if required

7. Other water-quality parameters

G. When samples are to be analyzed for metals and the final turbidity is greater than 5 NTUs, samples will be submitted for analysis of both total (unfiltered) and dissolved (filtered) metals, as described in Section 6.6.

H. Immediately seal each sample bottle when full. When all bottles are filled, place the samples on ice in a cooler within 15 minutes of completing sample set collection to maintain sample temperature preservation requirements in accordance with procedures outlined in the ENV-TI-05.80.02, Sample Labeling and Custody. Document the time that samples are placed on ice. Use of an ice bath may be considered during extremely hot sampling periods to maintain colder sample temperatures.

I. Document the sample identification and sample collection time before shipping on Chain of Custody (COC) record. Refer to ENV TI 05.80.03, Field Record Keeping.

J. Once sample collection is complete, measure and record turbidity and DTW. Also, reconnect the sampling tubing to the sonde and collect a final set of indicator parameter readings.

K. Once sampling is complete, de-energize the dedicated sampling pump prior to capping the well, replace the sample tubing, evacuate the downhole tubing, and close the protective casing.

L. When using a non-dedicated sampling pump and the sampling is complete, retrieve the sample pump and associated sampling equipment and decontaminate in accordance with procedures outlined in the ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination.

M. Close and secure the well. Clean up and remove debris left from the sampling event. Be sure that investigation-derived wastes are properly containerized and labeled.

N. Review sampling records for completeness. Add additional notes, as necessary.

6.5.2 Sampling after Purging with a Bailer

This section is to be followed for collection of groundwater samples after a purging with a bailer has been conducted, according to Section 6.4.2.

A. Measure and record the indicator parameter readings immediately prior to sample collection.

B. Record comments pertinent to the color and obvious odors, such as sulfur odor or petroleum hydrocarbons odor, associated with the water.

C. Arrange and label necessary sample bottles and ensure that preservatives have been pre-added to the sample bottles, as required. Include a unique sample number, time and date of sampling, the initials of the sampler, and the requested analyses on the label. Additionally, record information pertinent to the preservation used in the sample. Consult the facility-specific SAP and ENV-TI-05.80.04, Field Sampling Quality Control, to determine the appropriate QC samples to be collected.

D. Using the same bailer to purge the monitoring well, securely attach a new line (wire, cord, or rope) to the top of the bailer, ensuring that the line is of sufficient length for the bailer to reach the desired water level.

E. Lower the bailer into the well until the bailer contacts the surface of the water.

F. Allow the bailer to sink until the unit is filled with water. Do not allow the bailer to contact the well bottom.

G. Retrieve the bailer to the top of the well, while listening, to ensure the check valve is not leaking water back into the well. If the check valve is leaking, it may be necessary to bounce the unit up and down on the line to seal the valve.

H. Pour or drain the groundwater into sample bottles. Minimize turbulence when filling sample containers, especially for samples for VOCs, by allowing the liquid to run gently down the inside of each sample bottle. If project-specific documents (Work Plans, SAPs, QAPPs, etc.) do not specify a sample collection order, the labeled sample bottles are to be filled in the following order:

   1. Volatile Organic Compounds (VOCs)

   2. Semi-volatile Organic Compounds (SVOCs)

   3. Pesticides/Polychlorinated Biphenlys (PCBs)

   4. Total Petroleum Hydrocarbons (TPH)

   5. Metals, Cyanide, and Radionuclides

6.5.2 Sampling after Purging with a Bailer (continued)

6. Filtered Metals and radionuclides, if required
7. Other water-quality parameters

I. Immediately seal each sample bottle when full. When all bottles are filled, place the samples on ice in a cooler within 15 minutes of completing sample collection, to maintain sample temperature preservation requirements, in accordance with procedures outlined in the ENV-TI-05.80.02, Sample Labeling and Custody.

J. Record the sample identification appropriately and on the COC Record. Refer to ENV-TI-05.80.03, Field Record Keeping.

K. Once sampling is complete, dispose of properly.

L. Close and secure the well. Clean up and remove debris left from the sampling event. Be sure that investigation-derived wastes are properly containerized and labeled.

M. Review sampling records for completeness. Add additional notes, as necessary.

6.5.3 Sampling after Volume-Averaging Purge

This section is to be followed for collection of groundwater samples after a volume-averaged purge has been conducted. Volume-averaging purge methods are described in Section 6.4.3.

NOTE

Suction pumps (peristaltic pumps) may cause degassing, pH modification, and loss of VOCs; accordingly, peristaltic pumps (suction) are not recommended for use in collection of VOC samples (EPA 1996). Peristaltic pumps are acceptable for volume-averaged well purging and collection of groundwater samples for analyses other than VOCs. Samples analyzed for VOCs shall be collected with a bailer.

A. Measure and record the indicator parameter readings immediately prior to sample collection.

B. Record comments pertinent to the color and obvious odors, such as sulfur odor or petroleum hydrocarbons odor, associated with the groundwater.

6.5.3 Sampling after Volume-Averaging Purge (continued)

C. Arrange and label necessary sample bottles and ensure that preservatives have been pre-added to the sample bottles, as required. Include a unique sample number, time and date of sampling, the initials of the sampler, and the requested analyses on the label. Additionally, record information pertinent to the preservation used in the sample. Consult the facility-specific SAP and ENV-TI-05.80.04, Field Sampling Quality Control, to determine the appropriate QC samples to be collected.

D. If sampling with a pump, take care to minimize purge water descending back into the well through the pump tubing. Minimize turbulence when filling sample containers by allowing the liquid to run gently down the inside of the bottle. Labeled sample bottles should be filled in the following order:

1. Volatile Organic Compounds (VOCs)
2. Semi-volatile Organic Compounds (SVOCs)
3. Pesticides/PCBs
4. Total Petroleum Hydrocarbons (TPH)
5. Metals, Cyanide, and Radionuclides
6. Filtered Metals and Radionuclides, if required
7. Other water-quality parameters

E. If sampling with a bailer, refer to Section 6.5.2 for sample collection requirements. Refer to Step 6.5.3D of this section for bottle filling order. Minimize sample disturbance during collection.

F. Immediately seal each sample bottle, when full. When all bottles are filled place the samples on ice in a cooler within 15 minutes to maintain sample temperature preservation requirements in accordance with procedures outlined in the ENV-TI-05.80.02, Sample Labeling and Custody.

G. Record the sample identification and sample collection time appropriately and on the COC Record. Refer to ENV-TI-05.80.03, Field Record Keeping.

H. Once sampling is complete, retrieve the sample pump and associated sampling equipment and decontaminate, in accordance with procedures outlined in the ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination. If using a bailer, place used bailer back into sleeve and dispose of properly.

6.5.3 Sampling after Volume-Averaging Purge (continued)

I. Close and secure the well. Clean up and remove debris left from the sampling event. Be sure that investigation-derived wastes are properly containerized and labeled as specified in Section 6.9.

J. Review sampling records for completeness. Add additional notes, as necessary.

6.6 Filtration of Groundwater Samples

It will be necessary to collect filtered (dissolved) inorganic constituent samples in addition to unfiltered (total) inorganic constituent samples if the final turbidity value prior to sampling exceeds 5 NTU and/or if requested by the customer and/or required by the facility-specific SAP and QAPP. Dissolved sample collection is accomplished by filtering the sample, as follows:

A. When collecting samples, utilizing a pump (either low flow or submersible pump) as described in Section 6.5, attach a new certified-clean disposable in line 0.45 μm filter to the tubing.

B. Allow groundwater to run through the filter for two minutes. Either containerize the filter purge water or let it run on the ground, in accordance with the facility-specific SAP and QAPP. Document performance of the filter rinse/flush.

C. After the two-minute tube/filter flush, fill sample bottle(s) for dissolved inorganic constituents.

D. Ensure bottle(s) is labeled correctly and marked as a filtered sample.

E. After filtered samples have been collected, remove the in-line filter and continue filling remaining sample containers, if necessary.

F. Close and secure well, as detailed in Section 6.5.

6.7 Processing Field Samples

A. Once the investigatory and required QC samples are collected, ensure they are labeled correctly and that COC records are completed. See ENV-TI-05.80.02, Sample Labeling and Custody.

NOTE

Some concerns have arisen concerning the use of Sharpie-brand markers to label sample bottles. Caution should be used when using Sharpie-brand markers, especially when collecting samples for analysis of VOCs.

B. Procure laboratory-preserved sample containers, when possible. Handling of preservatives in the field poses health and safety, cross contamination and sample integrity concerns. If field preservation cannot be avoided, preserve samples that require preservation, as soon as practically possible, following sample collection, using traceable chemical preservatives obtained from the laboratory performing the sample analysis.

C. Complete the appropriate field documentation. Review sampling records for completeness and add notes, as needed.

D. Mark, package, and ship the samples to the designated laboratory for analysis, in accordance with the ENV-TI-05.80.06, Handling and Shipping of Samples.

6.8 Decontamination

Dedicated groundwater sampling equipment (submersible adjustable rate bladder pumps and sample tubing) will not require decontamination during each sampling event. Dedicated sampling equipment is to be decontaminated before deployment into the monitoring well when:

A. The pump is first deployed into the monitoring well.

B. The dedicated sampling pump is removed for routine, as described in the facility-specific SAP and ENV-TI-05.80.21, Monitoring Well Inspection and Maintenance, or non-routine maintenance.

C. Evaluation of analytical data reveals unusual or unexpected trending and sampling equipment is determined to be a potential cause.

D. As directed in writing by TVA and/or specified in the facility-specific SAP.

6.8 Decontamination (continued)

E. Sampling equipment that is not dedicated is to be decontaminated, as described in ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination.

F. Dedicated sample tubing is to be changed at the frequency stated in the facility-specific SAP, ENV-TI-05.80.21, Monitoring Well Inspection and Maintenance, or as directed by TVA.

6.9 Investigation-Derived Waste

Investigation-derived wastes, such as personal protective equipment (PPE), purged groundwater, waste media, and decontamination fluids are managed in accordance with Table 3, Investigative-Derived Wastes. Coordinate with appropriate TVA facility personnel to arrange for disposal of investigation-derived waste based on results of analytical data or in accordance with the facility-specific waste management plan.

Investigation-Derived Waste Stream	**Disposition Pathway**
General refuse (such as paper, plastic bags, and cardboard)	Dispose as municipal trash or recycle, as appropriate.
PPE (such as nitrile gloves and Tyvek®)	Dispose as municipal trash for routine activities. If expected to be contaminated with hazardous materials, containerize pending analytical results of associated samples.
Non-hazardous and potable groundwater	Release onto the ground down gradient of the monitoring well or based on TVA facility waste management requirements. Do not return water to the monitoring well.
Decontamination fluids	Containerize in appropriate containers dependent on user's knowledge and dispose of appropriately, based on TVA facility waste management requirements.

Table 3, Investigative-Derived Wastes

6.10 Field Logbooks and Data Sheets

A. Information associated with monitoring well inspection and maintenance is to be recorded in field logbooks, inspection checklists, and maintenance records as well as electronic data collection systems. Field work must be properly documented. Depending on the requirements of your organization, there are different mechanisms for recording. You must meet the requirements for your specific organization.

1. Electronic data collection system

2. Field logbooks

6.10 Field Logbooks and Data Sheets (continued)

3. Field worksheets (see Attachment 1, Example - Preliminary Groundwater Data Field Worksheet)

4. Field notebooks

5. Data sheets

B. Field logbooks, electronic data collection devices and systems, data sheets, and other appropriate field notebooks for recording daily activities are to be maintained by the Field Team Lead, or designee. Information is entered by the appropriate field team member using indelible ink when using bound logbooks.

C. In addition to the minimum requirements discussed in ENV-TI-05.80.03, Field Record Keeping, document those sampling characteristics specific to this TI and as defined in the applicable planning documents.

7.0 POST PERFORMANCE ACTIVITY

None

8.0 RECORDS

Records generated in the process of performing the activities in this TI must be processed and maintained as stated in the Environmental Records Matrix, in accordance with the TVA Document Services Records Management procedures.

8.1 Quality Assurance Records

A. Field logbooks, data sheets

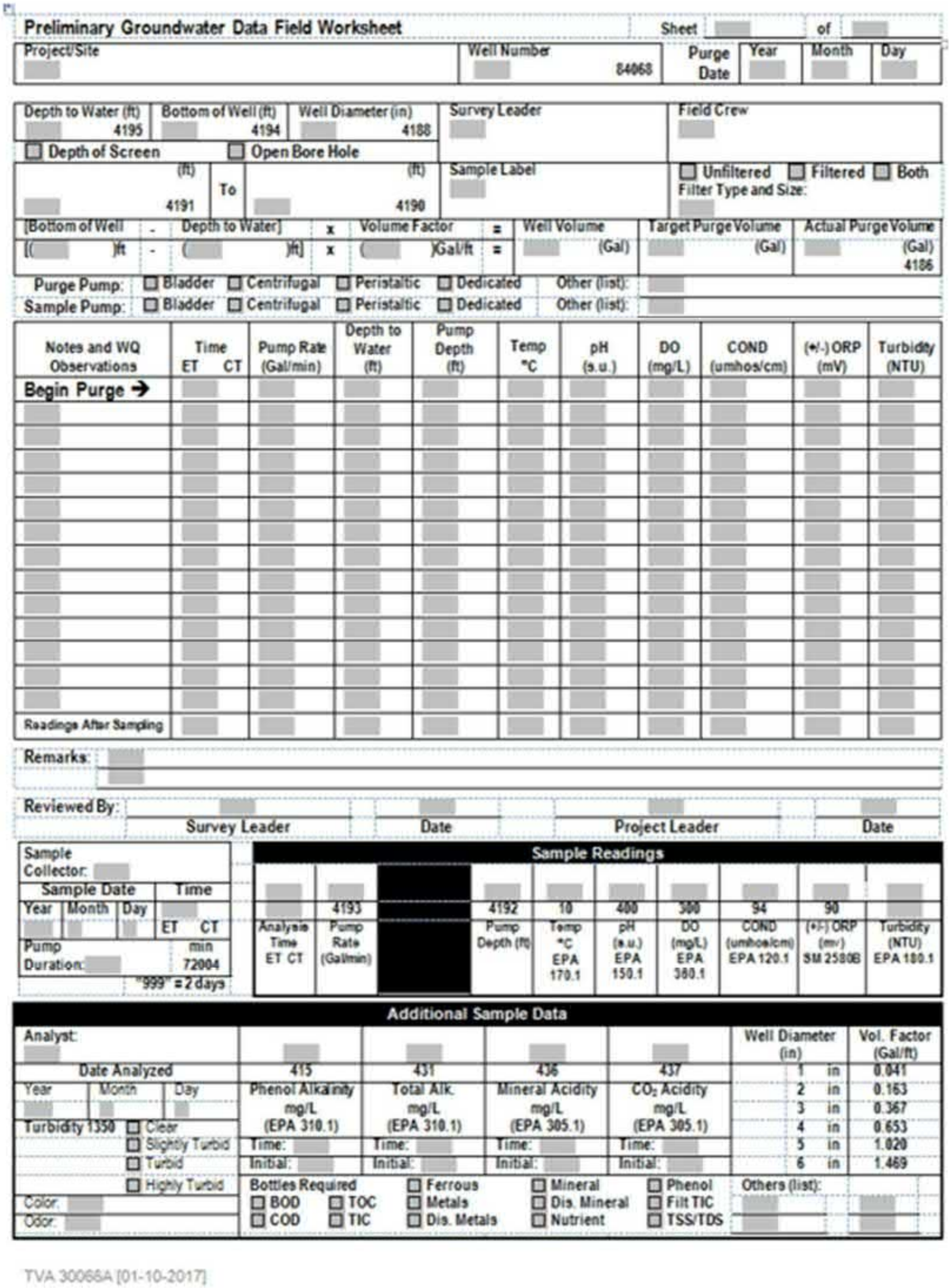
B. Chain of Custody Records

8.2 Non-Quality Assurance Records

Groundwater Sampling Equipment and Materials Checklist

Attachment 1
(Page 1 of 2)

Example - Preliminary Groundwater Data Field Worksheet



Preliminary Groundwater Data Field Worksheet Sheet ___ of ___

Project/Site	Well Number 84068	Purge Date	Year	Month	Day

Depth to Water (ft) 4195	Bottom of Well (ft) 4194	Well Diameter (in) 4188	Survey Leader	Field Crew

☐ Depth of Screen ☐ Open Bore Hole

(ft) 4191 To (ft) 4190

Sample Label

☐ Unfiltered ☐ Filtered ☐ Both
Filter Type and Size:

[Bottom of Well	-	Depth to Water]	x	Volume Factor	=	Well Volume	Target Purge Volume	Actual Purge Volume
[( )ft	-	( )ft]	x	( )Gal/ft	=	(Gal)	(Gal)	(Gal) 4186

Purge Pump: ☐ Bladder ☐ Centrifugal ☐ Peristaltic ☐ Dedicated Other (list):
Sample Pump: ☐ Bladder ☐ Centrifugal ☐ Peristaltic ☐ Dedicated Other (list):

Notes and WQ Observations	Time ET CT	Pump Rate (Gal/min)	Depth to Water (ft)	Pump Depth (ft)	Temp °C	pH (s.u.)	DO (mg/L)	COND (umhos/cm)	(+/-) ORP (mV)	Turbidity (NTU)
Begin Purge →										
Readings After Sampling										

Remarks:

Reviewed By: ___ Survey Leader ___ Date ___ Project Leader ___ Date

Sample Collector:

Sample Date			Time
Year	Month	Day	
			ET CT

Pump Duration: min 72004
"999" = 2 days

Sample Readings

	4193		4192	10	400	300	94	90	
Analysis Time ET CT	Pump Rate (Gal/min)		Pump Depth (ft)	Temp °C EPA 170.1	pH (s.u.) EPA 150.1	DO (mg/L) EPA 360.1	COND (umhos/cm) EPA 120.1	(+/-) ORP (mv) SM 2580B	Turbidity (NTU) EPA 180.1

Additional Sample Data

Analyst:

Date Analyzed		
Year	Month	Day

Turbidity 1350 ☐ Clear ☐ Slightly Turbid ☐ Turbid ☐ Highly Turbid

Color:
Odor:

415	431	436	437
Phenol Alkalinity mg/L (EPA 310.1)	Total Alk. mg/L (EPA 310.1)	Mineral Acidity mg/L (EPA 305.1)	CO_2 Acidity mg/L (EPA 305.1)
Time:	Time:	Time:	Time:
Initial:	Initial:	Initial:	Initial:

Well Diameter (in)	Vol. Factor (Gal/ft)
1 in	0.041
2 in	0.163
3 in	0.367
4 in	0.653
5 in	1.020
6 in	1.469

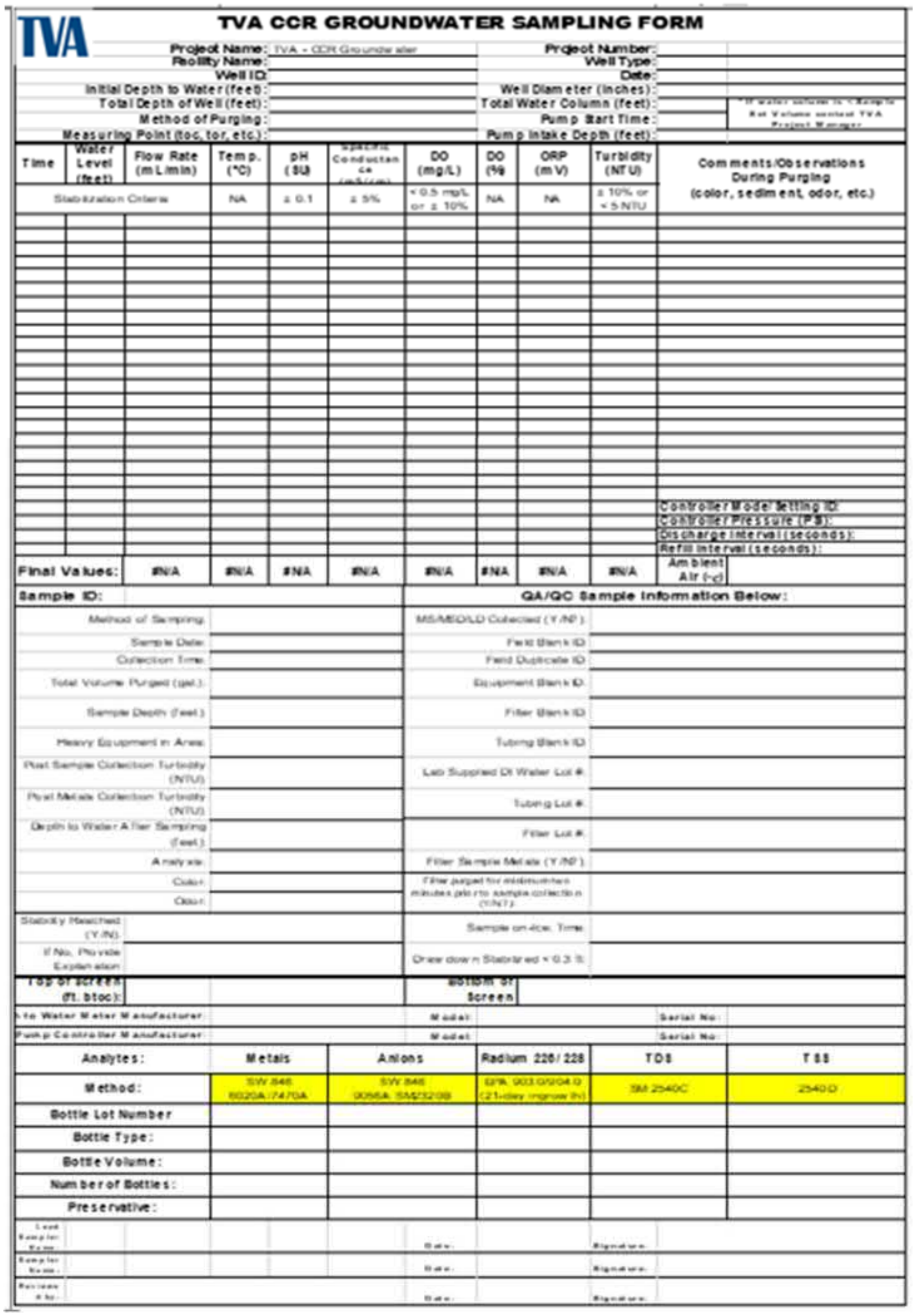
Bottles Required
☐ BOD ☐ TOC ☐ Ferrous ☐ Mineral ☐ Phenol
☐ COD ☐ TIC ☐ Metals ☐ Dis. Mineral ☐ Filt TIC
☐ Dis. Metals ☐ Nutrient ☐ TSS/TDS

Others (list):

TVA 30066A [01-10-2017]

Attachment 1
(Page 2 of 2)

Example - Preliminary Groundwater Data Field Worksheet



TVA

TVA CCR GROUNDWATER SAMPLING FORM

Project Name: TVA - CCR Groundwater
Facility Name:
Well ID:
Initial Depth to Water (feet):
Total Depth of Well (feet):
Method of Purging:
Measuring Point (toc, tor, etc.):
Project Number:
Well Type:
Date:
Well Diameter (inches):
Total Water Column (feet):
Pump Start Time:
Pump Intake Depth (feet):

**If water volume is < Sample Set Volume contact TVA Project Manager

Time	Water Level (feet)	Flow Rate (mL/min)	Temp. (°C)	pH (SU)	Specific Conductance (mS/cm)	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Comments/Observations During Purging (color, sediment, odor, etc.)
Stabilization Criteria			NA	± 0.1	± 5%	< 0.5 mg/L or ± 10%	NA	NA	± 10% or < 5 NTU	
										Controller Model Setting ID:
										Controller Pressure (PSI):
										Discharge Interval (seconds):
										Refill Interval (seconds):
Final Values:		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	Ambient Air (°C)

Sample ID:		**QA/QC Sample Information Below:**	
Method of Sampling:		MS/MSD/LD Collected (Y/N):	
Sample Date:		Field Blank ID:	
Collection Time:		Field Duplicate ID:	
Total Volume Purged (gal.):		Equipment Blank ID:	
Sample Depth (feet):		Filter Blank ID:	
Heavy Equipment in Area:		Tubing Blank ID:	
Post Sample Collection Turbidity (NTU):		Lab Supplied DI Water Lot #:	
Post Metals Collection Turbidity (NTU):		Tubing Lot #:	
Depth to Water After Sampling (feet):		Filter Lot #:	
Analysis:		Filter Sample Metals (Y/N):	
Color:		Filter purged for minimum [illegible] minutes prior to sample collection (Y/N):	
Odor:			
Stability Reached (Y/N):		Sample on ice: Time	
If No, Provide Explanation:		Draw down Stabilized < 0.3 ft:	

Top of Screen (ft. btoc):		**Bottom of Screen**			
to Water Meter Manufacturer:		**Model:**		**Serial No:**	
Pump Controller Manufacturer:		**Model:**		**Serial No:**	

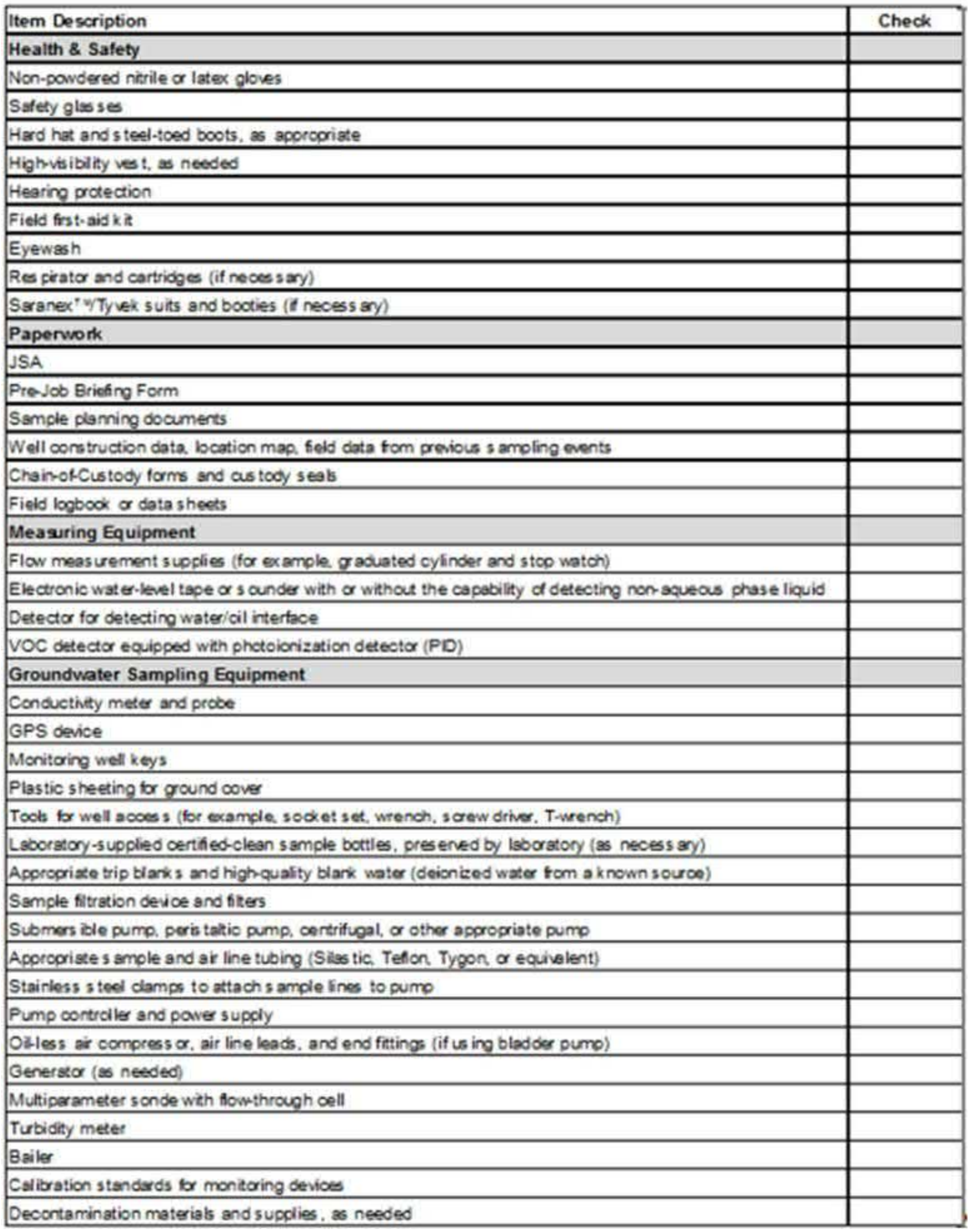
Analytes:	**Metals**	**Anions**	**Radium 226/228**	**TDS**	**TSS**
Method:	SW 846 6020A/7470A	SW 846 9056A, SM2320B	EPA 903.0/904.0 (21-day ingrowth)	SM 2540C	2540D
Bottle Lot Number					
Bottle Type:					
Bottle Volume:					
Number of Bottles:					
Preservative:					

Lead Sampler Name:		Date:		Signature:	
Sampler Name:		Date:		Signature:	
Reviewed By:		Date:		Signature:	

Attachment 2
(Page 1 of 1)

Example - Groundwater Sampling Equipment and Materials Checklist

Note: Calibration Standards for all monitoring devices are to be inspected to verify that they are within the expiration date listed on the container label.



Item Description	Check
Health & Safety	
Non-powdered nitrile or latex gloves	
Safety glasses	
Hard hat and steel-toed boots, as appropriate	
High-visibility vest, as needed	
Hearing protection	
Field first-aid kit	
Eyewash	
Respirator and cartridges (if necessary)	
Saranex™/Tyvek suits and booties (if necessary)	
Paperwork	
JSA	
Pre-Job Briefing Form	
Sample planning documents	
Well construction data, location map, field data from previous sampling events	
Chain-of-Custody forms and custody seals	
Field logbook or data sheets	
Measuring Equipment	
Flow measurement supplies (for example, graduated cylinder and stop watch)	
Electronic water-level tape or sounder with or without the capability of detecting non-aqueous phase liquid	
Detector for detecting water/oil interface	
VOC detector equipped with photoionization detector (PID)	
Groundwater Sampling Equipment	
Conductivity meter and probe	
GPS device	
Monitoring well keys	
Plastic sheeting for ground cover	
Tools for well access (for example, socket set, wrench, screw driver, T-wrench)	
Laboratory-supplied certified-clean sample bottles, preserved by laboratory (as necessary)	
Appropriate trip blanks and high-quality blank water (deionized water from a known source)	
Sample filtration device and filters	
Submersible pump, peristaltic pump, centrifugal, or other appropriate pump	
Appropriate sample and air line tubing (Silastic, Teflon, Tygon, or equivalent)	
Stainless steel clamps to attach sample lines to pump	
Pump controller and power supply	
Oil-less air compressor, air line leads, and end fittings (if using bladder pump)	
Generator (as needed)	
Multiparameter sonde with flow-through cell	
Turbidity meter	
Bailer	
Calibration standards for monitoring devices	
Decontamination materials and supplies, as needed	

Environmental Operations

Technical Instruction

ENV-TI-05.80.44

Groundwater Level and Well Depth Measurement

Revision 0000

Level of Use: Reference Use

Effective Date: 03-31-2017

Responsible Organization: Environmental Compliance and Operations

Prepared by: Diana Miles

Reviewed by: Donald W. Snodgrass Date: 03-30-2017

Concurred by: Donald E. McGee Date: 03-30-2017

Concurred by: Brian S. Fowler Date: 03-30-2017

Approved by: M. Susan Smelley Date: 03-31-2017

Revision Log

Revision or Change Number	Effective Date	Affected Page Numbers	Description of Revision/Change
0000	03/31/17	All	Initial Issue

Table of Contents

1.0 PURPOSE

This Technical Instruction (TI) provides the technical requirements and operational guidelines for measuring water levels and well depths with portable electronic water level meters. The measurement of the distance between the surface of a body of water and a fixed reference point (benchmark) above the water is frequently used to determine flow rates of rivers/creeks or water volumes of pools or ponds. The measurement of the groundwater level in a well is required when conducting groundwater sampling. Groundwater level and total well depth are needed to determine the volume of water or drawdown in the well casing for proper purging. For groundwater wells containing light non-aqueous phase liquids (petroleum products, for example) floating on top of the water, measurements can be performed using an oil/water interface probe or other specialized sensors to provide oil layer thickness, as well as groundwater levels.

2.0 SCOPE

A. This TI applies to TVA field sampling personnel and TVA contractors who perform groundwater level or well-depth measurements. using portable electronic water level meters for various regulatory and operational purposes.

B. This TI was developed under the general guidelines of the Environmental Protection Agency (EPA) SESDPROC-105, Groundwater Level and Well Depth Measurement.

Review Cadence: This TI will be reviewed every four years with the review documented in the Revision Log.

3.0 PRECAUTIONS/LIMITATIONS

3.1 Precautions

None

3.2 Limitations

None

4.0 REFERENCES

4.1 Performance References

A. ENV-TI-05.80.03, Field Record Keeping

B. ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination

C. ENV-TI-05.80.42, Groundwater Sampling

D. EPA, SESDPROC-105-R2, Groundwater Level and Well Depth Measurement

E. TVA-SPP-18.005, Plan Jobs Safely

4.2 Developmental References

None

4.3 Commitments

None

5.0 PREREQUISITE ACTIONS

None

6.0 PERFORMANCE

6.1 General Considerations

A. Field personnel conducting groundwater level or well depth measurements are required to be familiar with Environmental TI procedures, any facility-specific Sampling and Analysis Plan (SAP) and Quality Assurance Plan (QAP), as well as standard industry practices.

B. Potential hazards associated with groundwater level or well depth measurement activities are to be thoroughly evaluated prior to conducting field activities. During planning and sampling activities, procedures to ensure safety will be incorporated, according to the TVA Standard Programs and Processes (SPP) TVA-SPP-18.005, Plan Jobs Safely, which provides information on using job safety analyses (JSAs) and pre-job briefings (PJBs).

6.1 General Considerations (continued)

C. Care must be taken to avoid contamination or cross contamination of wells, especially drinking water wells. This is accomplished primarily by decontaminating the water level meters or measuring devices between wells as specified in ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination.

D. Sampling personnel are to wear powder-free nitrile or latex gloves when preparing and decontaminating instrumentation, and at all times while performing measurements.

E. Water level instruments are to be operated and maintained according to the manufacturer's specifications.

F. Refer to Attachment 1, Definitions.

6.2 Pre-Field Preparation

The Field Team Lead is responsible for ensuring that the following activities are completed before traveling to the site:

A. Prepare and/or review a diagram, chart, or plan, such as a facility-specific SAP, to determine the number of measurements to be performed.

B. Review JSA and identify needed safety equipment. Conduct a PJB.

C. Identify tools and other items needed for the measurement event. Obtain all equipment necessary for completing the water level or well depth measurements. See Attachment 2, Recommended Well Depth Measurement Equipment and Materials Checklist for an example checklist of equipment and materials.

D. Ensure all reusable equipment has been decontaminated, as specified in ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination, for decontamination instructions.

E. Verify that legal right-of-entry has been obtained and site access has been granted, where required, and that notice has been provided of the planned sampling event. Identify any potential site access logistical issues and take actions to address them prior to arriving at the site.

F. Obtain name and phone number of the site contact in case questions arise about the measurement process, where appropriate.

6.3 Instrument Calibration

A. Portable electronic water-level meters do not usually require calibration. Refer to the manufacturer's manual to determine if annual calibration is required for the specific meter being used to measure groundwater levels. If required, the meter should be calibrated annually against a National Institute of Standards and Technology-traceable measuring tape; e.g., Invar steel surveyor's tape. Measure the tape relative to the termination point of the electrode on the water meter probe. The meter is to be checked to within 0.01 foot per 10 feet of length, with an allowable error of 0.03 feet in the first 30 feet, as specified by SESDPROC-105-R2, EPA Groundwater level and Well Depth Measurement. The calibration is to be documented in the field logbook or instrument logbook maintained with the meter. If the meter is not functioning correctly or has been damaged, the meter is to be tagged as DO NOT USE and returned to the manufacturer for repair.

Step 6.3B Applies to CCR Only

B. Portable electronic water-level meters require annual calibration against a National Institute of Standards and Technology-traceable measuring tape; e.g., Invar steel surveyor's tape. Measure the tape relative to the termination point of the electrode on the water meter probe. The meter is to be checked to within 0.01 foot per 10 feet of length, with an allowable error of 0.03 feet in the first 30 feet, as specified by SESDPROC-105-R2, EPA Groundwater level and Well Depth Measurement. The calibration is to be documented in the field logbook or instrument logbook maintained with the meter. If the meter is not functioning correctly or has been damaged, the meter is to be tagged as DO NOT USE and returned to the manufacturer for repair.

6.4 Groundwater Level and Well Depth Measurement

A. Approach the monitoring well with caution, particularly in warm weather, watching for snakes, fire ants, wasp nests (may be inside well cover also), and other hazards.

B. Refer to ENV-TI-05.80.42, Groundwater Sampling for opening protective outer cover of monitoring well and during removal of sealing caps to allow for equilibrium.

6.4 Groundwater Level and Well Depth Measurement (continued)

C. Since water level and well depth measurements are made relative to a benchmark or reference point, inspect the platform or well casing for a benchmark. If no mark is apparent, establish a benchmark on the north side of a solid, stable plane of reference, such as a walkway, bridge railing, or well casing and make a permanent mark on the reference plane, such as notching the top of the casing or marking the outer edge of the casing with a permanent marker for metal wells. Record the location of the benchmark/reference point in the field records.

D. Ensure the meter is powered up, has its sensitivity control adjusted per manufacturer's directions, and is set to give both audible and visual alarms, if possible. Ensure the instrument is capable of measuring in the correct units (feet or meters) for the customer's needs.

E. For water level measurements, perform the following steps:

1. Lower the probe end of the meter tape into the well, or toward the water surface, and listen for the audible alarm.

2. When the alarm sounds, stop lowering the probe. Pull the tape up slightly until the alarm ceases.

3. Ensure the tape is next to the benchmark point of the well casing or platform and slowly lower the tape until the alarm again activates.

4. Observe the tape markings at the benchmark point and read to the nearest 0.01 foot (0.03 meter).

5. Repeat Steps 6.4E.1 through 6.4E.4, as needed, to ensure an accurate measurement.

6. Record the measurement, along with the date, time, and operator's initials in the field logbook, data sheet, or other appropriate field notebook in accordance with ENV-TI-05.80.03, Field Record Keeping. Electronic records are acceptable.

F. For well depth (depth to bottom) measurements, perform the following steps. The meter is to be turned off for this measurement.

1. Lower the probe end of the meter tape into the well until the probe touches the bottom of the well. The tape will usually go slack at this point.

2. Ensure the tape is next to the benchmark point of the well casing.

3. Gently pull up on the tape until it just becomes taut.

6.4 Groundwater Level and Well Depth Measurement (continued)

4. Observe the tape markings at the benchmark point and read to the nearest 0.01 foot (0.03 meter).

5. Repeat Steps 6.4E.1 through 6.4E.4, as needed, to ensure an accurate measurement.

6. Ensure the correct measuring point is used based on the electrode location of the depth-to-water level meter used. On some models, the tape markings are referenced to the electrode termination point rather than the end of the probe, and this length of the probe beyond the electrode must be accounted for.

7. Record the measurement, along with the date, time, and sampler's initials in the field logbook, data sheet, or other appropriate field notebook, as specified by ENV-TI-05.80.0, Field Record Keeping. Electronic records are acceptable.

G. For oil layer detection/thickness, ensure the oil/water interface meter has the correct sensor(s) and is selected for the correct units (feet or meters). Ensure the meter is powered up, has its sensitivity control adjusted per manufacturer's directions, and is set to give both audible and visual alarms, if possible. Perform the following steps:

1. Lower the probe end of the meter tape into the well, or toward the water's surface, while listening for the audible oil-layer alarm.

2. When oil contact with the probe causes alarm activation, halt the meter tape. Pull the tape up slowly until the alarm ceases.

3. Ensure the marked tape is adjacent to the benchmark point of the well casing or platform and slowly lower the tape until the alarm again activates.

4. Observe the tape markings at the benchmark point and read to the nearest 0.01 foot (0.03 meter).

5. Repeat Steps 6.4G.1 through 6.4G.4, as needed, to ensure an accurate measurement.

6. Record the measurement, along with the date, time, and sampler's initials in the field logbook, data sheet, or other appropriate field notebook, as specified by ENV-TI-05.80.03, Field Record Keeping. Electronic records are acceptable.

7. Continue to lower the probe until water contact activates the water layer alarm.

6.4 Groundwater Level and Well Depth Measurement (continued)

8. Record the measurements, along with the date, time, and sampler's initials in the field logbook, data sheet, or other appropriate field notebook, as specified by ENV-TI-05.80.03, Field Record Keeping. Electronic records are acceptable.

9. Calculate thickness of oil layer by subtracting the oil layer level from the water layer level. Record the calculated oil layer thickness in field logbook, data sheet, or other appropriate field notebook, as specified by ENV-TI-05.80.03, Field Record Keeping. Electronic records are acceptable.

H. In order to minimize cross contamination, scrub the probe and any portion of the measuring tape, which has been immersed in water or oil, with phosphate-free soap, such as Liqui-Nox® or Luminox®, and then rinse with DI water between wells, as specified by ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination.

6.5 Investigation-Derived Waste

Investigation-derived wastes, such as personal protective equipment (PPE), waste media, and decontamination fluids will be managed, in accordance with Table 1, Investigation-Derived Waste Stream. Coordinate with appropriate facility personnel to arrange for disposal of investigation-derived waste based on the results of analytical data or in accordance with the facility-specific waste management plan.

Investigation-Derived Waste Stream	Disposition Pathway
General refuse (such as paper, plastic bags, and cardboard)	Dispose as municipal trash or recycle as appropriate.
PPE (such as nitrile and latex gloves)	Dispose as municipal trash for routine activities.
Decontamination fluids or waste waters	Containerize in appropriate containers dependent on user's knowledge, and dispose appropriately based on analytical results.

Table 1, Investigation-Derived Waste Stream

6.6 Field Logbooks and Data Sheets

Field logbooks, field notebooks, and field data sheets recording daily activities are to be maintained by the Field Team Leader, or designee. Information is to be entered using indelible ink. In addition to the minimum requirements discussed in ENV-TI-05.80.03, Field Record Keeping, the field logbooks, field notebooks, and data sheets are to document those sampling characteristics specific to the latest revision of this TI, and as defined in the applicable sample planning and control documents.

7.0 RECORDS

Records generated in the process of performing the activities in this TI must be processed and maintained as stated in the Environmental Records Matrix, in accordance with the TVA Document Services Records Management procedures.

7.1 Quality Assurance Records

A. Field logbooks and data sheets

7.2 Non-Quality Assurance Records

None

Attachment 1
(Page 1 of 1)

Definitions

Oil/water interface meter - An electronic water level meter which possesses a second sensor, usually an infrared emitter/receiver circuit, in the weighted probe for detecting petroleum compounds, such as oil, floating on top of water. This type of instrument emits a different audible tone when oil is encountered than when water is encountered, thereby allowing the determination of the thickness of the oil layer.

Water level - The accurately measured distance from the conductor termination point on the meter probe (potentiometric surface measurement) to a benchmark/reference point. For groundwater gradients, the reference point is to be tied to the National Geodetic Vertical Datum or a local datum. For wells, the reference point/benchmark is usually located on north side of the top of the well casing. Electronic water level meters usually consist of an energy source (battery), a spool of dual conductor wire embedded in a plastic tape, a weighted probe at the distal end of the tape, and an alarm circuit. The plastic tape serves as an electrical insulator between two wire conductors as well as being an accurately marked measuring device. The weighted probe at the distal end of the tape is the terminating point for the wire conductors and may also contain a sensor for detection of petroleum compounds (oil). The alarm circuit usually consists of an audible enunciator linked to the two wire conductors (some meters also are equipped with a visible alarm). When the electrical conductors in the weighted probe both make contact with the surface of the water, an electrical circuit is completed and the alarm circuit is triggered. Measurements are made to the nearest 0.01 foot.

Attachment 2
(Page 1 of 1)

Recommended Well Depth Measurement Equipment and Materials Checklist

Item Description	Check
Health & Safety	
Hearing protection	
Non-powdered nitrile or latex gloves	
Field first-aid kit and eyewash	
Hard hat and steel-toed boots	
Safety goggles	
Reflective safety vest	
Paperwork	
JSA and PJB	
Project work and sampling planning documents	
Field logbook, data sheets, and/or other appropriate field notebooks	
Well Depth Measurement Equipment and Materials	
Water level meter	
Oil / water interface meter	
Replacement batteries	
DI water	
Invar steel surveyor’s chain (if calibrating meter)	
Decontamination solutions and waste management supplies	

TVA

Environmental Operations

Technical Instruction

ENV-TI-05.80.46

Field Measurement Using a Multi-Parameter Sonde

Revision 0001

Level of Use: Reference Use

Effective Date: 09-16-2019

Responsible Organization: Environmental Compliance and Operations

Prepared by: Environmental Compliance and Operations

Reviewed by: Donald W. Snodgrass Date: 08-29-2018

Concurred by: James Osborne Date: 09-03-2019

Approved by: Brian S. Fowler Date: 09-03-2019

Approved by: M. Susan Smelley Date: 09-09-2019

Revision Log

Revision or Change Number	Effective Date	Affected Page Numbers	Description of Revision/Change
0000	03/31/16	All	Initial Issue
0001	9/16/19	All	Removed CCR information, made changes throughout

Table of Contents

Table of Contents (continued)

1.0 INTRODUCTION

1.1 Purpose

This Technical Instruction (TI) describes the standardization, documentation, and maintenance requirements for using a multi-parameter sonde for conducting water quality measurements. A sonde is a group of sensors configured together with a digital device in addition to a data logger for recording the output of multiple sensors. This TI specifically provides the details on how to:

- Standardize a multi-parameter sonde,
- Collect field measurements, and
- Perform general sonde maintenance.

2.0 SCOPE

A. This TI applies to TVA field sampling personnel and TVA contractors who use a multi-parameter sonde to conduct water quality measurements for various regulatory and operational purposes.

B. Multi-parameter sondes are available from several manufacturers. Due to the wide variety of meters available, detailed operating procedures cannot be incorporated into this TI. Field personnel are to be acquainted with the operation of the particular meter being used by consulting the manufacturer's operation/user's manual.

C. Prior to selecting a type of multi-parameter sonde for use, field personnel should ensure that the instrument is, at a minimum, able to perform all the measurements required for that specific project, such as, temperature, dissolved oxygen (DO), specific conductance (SC), oxidation-reduction potential (ORP), turbidity (surface water), and pH. The multi-parameter sonde utilized must be able to measure temperature, dissolved oxygen (DO), specific conductance (SC), oxidation-reduction potential (ORP), pH, and turbidity (if using the Sonde for Surface Water Measurements). When measuring groundwater quality parameters, turbidity values are to be measured using a stand-alone turbidimeter, even if the multi-parameter sonde is capable of supporting a turbidity probe.

D. This TI was developed under the general guidelines of the US Environmental Protection Agency (US EPA) Region 4, operating procedures for field measurement and the Standard Methods for the Examination of Water and Wastewater (SMWW), as referenced in “Table 1, Standard Methods.”

2.0 SCOPE (continued)

Parameter	Standard Method Section	EPA References
Sonde	--	SESDPROC-111
Turbidity	2310 B	SESDPROC-103
Temperature	2550 B	SESDPROC-102
Dissolved Oxygen (DO)	4500-O G	SESDPROC-106
Specific Conductance (SC)	2510 B	SESPDROC-101
pH	4500-H B	SESDPROC-100
Oxidation Reduction Potential	2580	SESDPROC-113

Table 1, Standard Methods

E. Procedures for measuring parameters, using specific instruments, are defined in individual TI, such as ENV-TI-05.80.61, pH and Temperature Measurement.

Review Cadence: This TI will be reviewed every four years with the review documented in the Revision Log.

3.0 REFERENCES

3.1 Performance References

A. ENV-TI-05.80.03, Field Record Keeping

B. ENV-TI-05.80.04, Field Sampling Quality Control

C. ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination

D. ENV-TI-05.80.42, Groundwater Sampling

E. ENV-TI-05.80.40, Surface Water Sampling

F. ENV-TI-05.80.61, pH and Temperature Measurement

G. American Public Health Association, Water Works Association, and Water Environment Federation, variously dated, Standard Methods for the Examination of Water and Wastewater (SMWW)

H. TVA-SPP-18.005, Plan Jobs Safely

3.2 Developmental References

A. J.H.Wilde, F.D., Sandstrom, M.W., and Skrobialowski, S.C., 2014, Selection of equipment for water sampling (ver. 3.1): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A2, April 2014, accessed May 1, 2014

B. US EPA, Region 4, SESDPROC-100-R4, Field pH Measurement, 2016

C. US EPA, Region 4, SESDPROC-101-R6, Field Specific Conductance Measurement, 2016

D. US EPA, Region 4, SESDPROC-102-R4, Field Temperature Measurement, 2014

E. US EPA, Region 4, SESDPROC-103-R4, Field Turbidity Measurement, 2017

F. US EPA, Region 4, SESDPROC-106-R4, Field Measurement of Dissolved Oxygen, 2017

G. US EPA, Region 4, SESDPROC-111-R3, In Situ Water Quality Monitoring, 2013

H. US EPA, Region 4, SESDPROC-113-R2, Field Measurement of Oxidation-Reduction Potential (ORP), 2017

3.3 Commitments

None

4.0 PRECAUTIONS AND LIMITATIONS

4.1 Precautions

None

4.2 Limitations

None

5.0 PREREQUISITE ACTIONS

None

6.0 PERFORMANCE

6.1 General Considerations

A. Field personnel operating multi-parameter sondes are required to be familiar with the procedures provided in this TI and facility-specific Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP), as well as standard industry practices, and the manufacturer's operator manual for the water quality instrumentation being used.

B. Field work must be properly documented. Depending upon the requirements of your organization, there are a number of different mechanisms for recording field data. You must meet the requirements for your specific organization.

1. Groundwater Application, or other electronic data collection system
2. Field logbooks
3. Field worksheets
4. Field notebooks
5. Data sheets

C. Field personnel are to be trained by personnel experienced in operating the instrument(s) before operating the sonde and the sensors and data logger. Sondes may house multiple sensors selected from Table 2, Sensors, for in situ water-quality measurements.

Conductivity	Ammonium
Temperature	Nitrate
pH	Chloride
Oxidation-reduction potential (ORP)	Total dissolved solids (TDS)
Dissolved oxygen (DO)	Total dissolved gases
Turbidity	Chloropyll
Depth	Rhodamine
Salinity	Blue-green algae
	Crude oil

Table 2, Sensors

6.1 General Considerations (continued)

D. Potential hazards associated with the planned field water quality measurements shall be thoroughly evaluated prior to conducting field activities. During planning and sampling activities, procedures to ensure safety will be incorporated according to TVA-SPP-18.005, Plan Jobs Safely, which provides information on using job safety analyses (JSAs) and pre-job briefings (PJBs).

E. For those projects where it has been determined that a job safety analysis (JSA) is required, review the Job Safety Analysis (JSA) Worksheet - Form 15943, and identify needed safety equipment. Once the work activities are complete conduct a post-job meeting and document the meeting using the Post-Job Review Checklist - Form 40899. For those tasks where it has been determined that only verbal pre- and post-job briefings are required, make sure to cover all pertinent safety topics associated with the task.

F. Since the collection of water quality data involve operations in a body of water (river, stream, lake, pond, or outfall), water safety hazards shall be thoroughly considered, evaluated, and understood prior to conducting sampling activities in the vicinity of surface water. When working in and on the water, the two-person rule (buddy system) should be implemented whenever possible. Personnel entering waters on foot or in a vessel shall wear a U.S. Coast Guard-approved flotation device, wherever necessary, or as mandated by U.S. Coast Guard, federal, state, or local regulations. In general, personnel shall not wade into flowing water when the product of depth (in feet) and velocity (in feet per second) equals 10 or greater (rule of thumb from U.S. Geological Survey). If flow data are unavailable, personnel should not exceed a water depth of knee height. For sample locations that are a considerable distance from the shoreline, a boat, barge, dock, or bridge may be employed for sampling. Safety hazards and precautions for operations that occur on the water should be addressed in a JSA and discussed in the PJB before field measurement/sampling is initiated.

6.2 Pre-Field Preparation

Prior to leaving for the site, the Field Team Lead is responsible for ensuring that the following activities have been completed:

A. Prepare and/or obtain and review a sampling diagram, chart, or plan, such as a facility-specific SAP, that designates the equipment to be used, specific standardization procedures, number of measurements planned and locations/depths. For smaller or short-duration tasks, provide a description of all work procedures during the pre-job briefing. If sampling plan does not address quality control (QC) measurements, refer to ENV-TI-05.80.04, Field Sampling Quality Control.

6.2 Pre-Field Preparation (continued)

B. For those projects where it has been determined that a job safety analysis (JSA) is required, review the Job Safety Analysis (JSA) Worksheet - Form 15943, and identify needed safety equipment. Conduct a Pre-Job meeting prior to beginning work and document on the Pre-Job Brief Checklist – Form 40898. Once the work activities are complete, conduct a post-job meeting and document the meeting using the Post-Job Review Checklist - Form 40899.

C. Identify and obtain items needed for the water quality measurements, including calibration/standardization procedures. A suggested equipment checklist is provided in Attachment 1, Recommended Multi-Parameter Sonde Equipment and Materials Checklist. Attachment 1 is not intended to be all inclusive and is provided only as an example.

D. Review maintenance record or log for the sonde to ensure unit has been factory-calibrated and within its calibration expiration date. The unit's maintenance log is not to be taken into the field and is to be maintained as a quality assurance record.

E. If a boat is required, notify the TVA Project Manager or designee of the date, location, and the personnel involved with collecting the samples. Alternatively, a float plan may be submitted to the TVA Project Manager. A float plan includes a description of the water vessel, specifies who is on board, provides a description of the safety equipment being carried, and indicates destination and expected time of return. See Attachment 2, Example - TVA Boating Float Plan.

F. Obtain potable and lab-supplied deionized (DI) water for decontamination. Record the water source in the field logbook, data sheet, or other appropriate field notebook. Verify that the multi-parameter sonde and other sampling equipment have been cleaned, in accordance with ENV-TI-05.80.05, Field Equipment Cleaning and Decontamination*,* or manufacturer's instructions.

G. If required, provide the customer with the sampling schedule. Verify that site access and legal right-of-entry has been obtained, where required. Pre-identify any potential site access logistical issues and take actions to address them.

H. Ensure the sonde has been charged and/or fresh batteries have been obtained. Ensure the sondes and data-logger(s) connect and are communicating with each other. It is recommended that a back-up standardized sonde and data-logger be obtained.

6.3 Sonde Standardization

A. The multi-parameter sonde being utilized for water quality (surface water or groundwater) field measurements undergoes documented calibration (hereinafter, standardization) prior to use each day following the procedures outlined in the manufacturers operating/user’s manual. The procedures included in this TI provide general requirements for standardization and requirements for standardization verification ranges. The recommended order for calibration/standardization of the individual sensors on a sonde is conductivity, temperature, pH, DO, followed by turbidity and other sensors (if monitoring a matrix other than groundwater) and ORP. Any standardization solutions used during the processes described in this TI are to be accredited by the vendor and used within the expiration date of the solutions. Record the standardization information on Attachment 3, Example - Field Standardization of Instruments, or equivalent. Notify the TVA Project Manager or the customer if the instrument cannot be standardized within the acceptance criteria calibration during field use.

B. Since more than one sensor is located within the same housing of a sonde and all of the sensors will come in contact with the calibration/standardization standards, it is extremely important to prevent cross-contamination during the standardization procedures by rinsing the probes with DI water after each standardization.

6.3.1 Specific Conductivity

A. Refer to the operator’s manual to determine the standardization process for the specific conductivity or SC meter.

B. The conductivity standards are much more sensitive to cross contamination and dilution than other standards. Therefore, all the probes are to be thoroughly rinsed and dried prior to immersion in a conductivity standard. Besides being easily diluted, specific conductivity can affect other parameters, such as DO in groundwater and source discharges; therefore, the specific conductivity is to be the first parameter calibrated/standardized.

C. The procedures outlined in the manufacturer’s operation/user’s manual are to be used for the standardization of the specific conductivity probe. In addition, the following requirements also apply:

1. Rinse sensor with DI water prior to standardization and prior to measuring a second standard solution (if a 2 point standardization is being used).

2. Use fresh, new standard solution during standardization and properly discard standard solutions after use.

3. After standardization is complete verify the probe has been properly standardized by measuring an aliquot of fresh, new standard solution.

6.3.1 Specific Conductivity (continued)

4. The acceptable standardization range for SC is plus or minus ten percent of the known standard concentration.

5. Instruments that do not meet this requirement during standardization are to be tagged as DO NOT USE, removed from service, and returned to the manufacturer for maintenance.

6.3.2 Temperature

A. The temperature sensor is not standardized. However, it should be checked each day of sampling against a National Institute of Standards and Technology (NIST) traceable thermometer with 0.1 degree temperature increments.

B. Record the NIST thermometer identification number and calibration date on Attachment 3, Example - Field Standardization of Instruments.

1. Place the sonde and the NIST-traceable thermometer (non-mercury) in a container of water.

2. Allow both devices to stabilize, approximately 20 to 30 seconds.

3. The amount of acceptable temperature variation for the reading between the sonde and the NIST thermometer varies, depending on the sampling program. The typical surface water amount of allowable variations include 0.15°C, 0.2°C and 0.5°C.

4. If the temperature reading recorded from the sonde is greater than plus or minus 4°C of the NIST thermometer reading, a correction factor can be applied to field measurements, depending on specific program requirements, equal to the difference between the NIST thermometer and sonde reading as follows:

    a. Add the correction factor to each reading, OR

    b. Subtract the correction factor from each reading

    c. Clean and properly store the NIST-traceable thermometer.

    d. Apply this correction factor to temperature measurements recorded by that sonde during both standardization and field measurements.

5. Alternatively, if the temperature reading of the sonde is not within the amount of allowable variations of the NIST thermometer reading, remove the sonde from service and return to manufacturer for maintenance.

6.3.3 pH

NOTE

The pH value of the buffer solutions are certified at a standard temperature (typically 25°C). The pHs of those buffer solutions change as their temperature deviates from the standard temperature. Some meters have the capacity to read back the temperature-adjusted pH of the buffer solution, and that value or a value derived from an approved conversion or calculation is to be used as the reference calibration value at non-standard temperatures.

A. The pH sensor is sensitive to the temperature of the samples, especially in the alkaline range. Ideally, the calibration buffers and samples should remain at the same temperature during standardization and measurement. Modern pH measuring instruments are equipped with automatic temperature compensation (ATC) to eliminate the thermal effect. In addition, the automatic buffer recognition capability of the instrument automatically compensates the temperature effect on the pH of the buffer solutions. Depending on the program requirements and the instrument manufacturer's recommendations either a two-point or a three-point standardization is required. For most surface water sampling, a two-point standardization is required for pH using NIST-traceable buffer solutions of pH 7.0 and 10.0 standard units (s.u.). A reading must be taken for pH 4.0, but does not need to be standardized. For most groundwater programs, a three-point standardization is required for pH using NIST-traceable buffer solutions of pH 7.0, 4.0, and 10.0 standard units (s.u.).

B. The procedures outlined in the manufacturer's operation/user's manual are to be used for the standardization of the pH probe. In addition, the following requirements also apply:

1. Select the 7.0 pH buffer solution first.

2. Pour a small amount of fresh pH buffer solution in the storage cup and rinse the sensors. Discard the rinse solution properly.

3. Pour enough fresh pH buffer solutions in the storage cup to adequately cover the pH and the reference sensors.

4. Standardize pH to the pH buffer solution's given value. Record the observed temperature for buffer solutions next to Buffers Temp and the pH in the Adjusted To column on Attachment 3, Example - Field Standardization of Instruments.

5. Repeat Steps 6.3.3B.2 through 6.3.3B.4 with the other pH buffer solutions, as recommended by the manufacturer.

6.3.3 pH (continued)

6. Properly discard the pH buffer solution after each use and rinse the sensors and storage cup with DI water.

7. After completing the standardization, pour fresh 7.0 pH buffer solution in the storage cup and record the measurement. The acceptable standardization range for pH is plus or minus 0.2 s.u. Record the instrument reading on Attachment 3, Example - Field Standardization of Instruments.

NOTE

For programs that require regulatory reporting of field pH data the acceptable standardization range will be more stringent than stated in Section 6.3.3B.7. Possible acceptable standardization range could be +/- 0.1 s.u. or as stringent as +/- 0.05 s.u.

8. Instruments that do not meet the standardization criteria should be removed from service, tagged as DO NOT USE, and returned to the manufacturer for maintenance.

6.3.4 Dissolved Oxygen

A. The dissolved oxygen (DO) sensor is sensitive to the temperature of the sample. Modern DO sensors, especially the optical DO sensor, are equipped with accurate thermometers for temperature compensation. The concentration of the DO (in mg/L) is calculated by the instrument after measuring the response of the instrument to partial pressure of the dissolved oxygen under the atmospheric pressure at the site. DO is standardized at 100 percent saturation (air-saturated water or water-saturated air) according to the theoretical solubility of oxygen under the current temperature, pressure, and salinity. Modern DO sensors compensate the effect of temperature and salinity (measure by conductivity) during standardization and measurement.

B. The procedures outlined in the manufacturer's operation/user's manual are to be used for the standardization of the DO probe. In addition, the following requirements also apply:

6.3.4 Dissolved Oxygen (continued)

NOTE

Some meters with depth sensors have the capability of obtaining the BP directly.

1. Obtain an accurate true barometric pressure (BP) reading for the site immediately prior to optical DO standardization. If the BP is obtained from the National Weather Service, it is usually already adjusted to sea level. If not, or if it is obtained from other local weather services, adjust the BP reading to sea level. Record the BP and source of information on Attachment 3, Example - Field Standardization of Instruments.

NOTE

If there is a change in barometric pressure after calibration (e.g., if the barometric pressure drops as you move the calibrated instrument to a higher elevation) the readings for DO percent saturation will not be correct. A new barometric pressure must be entered. However, the readings for DO mg/L will be correct regardless of changes in barometric pressure.

2. If the barometric pressure reading for the site's altitude required correction, use the following equation:

   $BP_{alt} = BP_{SL} – 2.5(A/100)$ where:

   a. BP_{alt} = barometric pressure at altitude

   b. BP_{SL} = barometric pressure at sea level

   c. A = altitude (feet above sea level)

C. Standardize the optical DO to 100 percent saturation (air or water). Standardization may be verified by either DO in mg/L or DO as a percentage.

1. For DO in mg/L check the DO concentration (in mg/L) against the value in the dissolved oxygen solubility table. The acceptable standardization range for optical DO is plus or minus 0.5 mg/L.

2. For DO as a percentage the acceptable standardization range is plus or minus 5 percent.

D. Instruments that do not meet the standardization criteria are to be removed from service, tagged as DO NOT USE, and returned to the manufacturer for maintenance.

6.3.5 Turbidity

A. Standardization of the turbidimeter is to be conducted in accordance with the manufacturer’s recommendations. Record the instrument readings on Attachment 3, Example - Field Standardization of Instruments. A separate turbidimeter is required when measuring turbidity during groundwater monitoring.

B. If standardizing a turbidity probe from a multi-parameter sonde for use during surface water monitoring, perform at least a two-linear standardization using a less than 1.0 or 10.0 NTU turbidity standard solution first, followed by 100, 400, 800, or 3000 NTU turbidity standard solutions, depending on the expected range of turbidity to be measured. For standardizing a turbidimeter for use during groundwater monitoring, perform at least a two-point standardization using a 0.1, 20, and 100 NTU standards. Then perform a 10 NTU verification or the standard that most closely matches expected turbidity readings.

C. After the standardization, perform a standardization verification check using the NTU standard as recommended by the manufacturer or using the NTU standard that most closely matches expected turbidity readings that will be measured during the day. Use field turbidity data collected at that site during a previous event to select the standardization verification check concentration from the concentrations used during standardization. Record the measurement on Attachment 3, Example - Field Standardization of Instruments. The acceptable standardization range is plus or minus three percent of the known standard value.

D. Instruments that do not meet the standardization criteria are to be removed from service, tagged as DO NOT USE, and returned to the manufacturer for maintenance.

6.3.6 Oxidation-Reduction Potential

A. Standardization of the oxidation-reduction potential (ORP) sensor must be conducted after standardization of the pH sensor. If pH cannot be standardized, the sonde is set aside for further evaluation.

B. The procedures outlined in the manufacturer’s operation/user’s manual are to be used for the standardization of the ORP probe. In addition, the following requirements also apply:

1. Clean the ORP sensor as recommended by the manufacturer.
2. Rinse the sensor with DI water.

6.3.6 Oxidation-Reduction Potential (continued)

WARNING

Quinhydrone is a known irritant and carcinogen. Nitrile gloves and safety glasses are to be worn when handling and mixing quinhydrone. Refer to the quinhydrone material safety and data sheet (SDS) for additional safety measures. Dispose of quinhydrone in accordance with Section 6.6.

3. Use either Zobell’s solution or quinhydrone solution to standardize the ORP sensor. Use the solution recommended by the manufacturer for standardization.

4. Quinhydrone comes as a powder that must be added and mixed in a pH 7.0 buffer solution until the solution is saturated with quinhydrone (some crystals will be visible).

5. Shake the unit vigorously for about six seconds.

6. Properly discard the Zobell’s or quinhydrone solution.

7. Fill the storage cup with Zobell’s or quinhydrone solution again. Fill the cup until the pH sensor and reference are covered.

8. Wait for approximately one minute for the reading to stabilize.

9. When using Zobell’s solution, perform a calculation, using the following equation:

   ORP (mV) = 228 - [2.2 x (T-25)] where T is solution temperature in °C

10. Standardize the ORP probe to this value.

11. When using quinhydrone in pH 7.0 solution, perform a calculation using the following equation:

    ORP (mV) = 85 – [2.0 x (T-25)] where T is solution temperature in °C

12. Standardize the ORP probe to this value.

13. When using quinhydrone in pH 7.0 solution, perform a calculation using the following equation:

    ORP (mV) = 85 – [2.0 x (T-25)] where T is solution temperature in °XC

14. Standardize the ORP probe to this value.

6.3.6 Oxidation-Reduction Potential (continued)

15. Rinse probe thoroughly with distilled or DI water and blot dry with a clean lint-free cloth or wipe.

16. After the standardization, perform a standardization verification check using fresh, new solution. Record the measurement on Attachment 3, Example - Field Standardization of Instruments. The acceptable standardization range is plus or minus 10mV of the known standard value.

17. Instruments that do not meet the standardization criteria are to be removed from service, tagged as DO NOT USE, and returned to the manufacturer for maintenance.

6.4 Collection of Field Measurements

Once the sonde has been standardized for the appropriate parameters, it is ready to be used for collecting field measurements as follows.

A. Attach the appropriate data logger or electronic recording device to the sonde in order to collect field parameters. Refer to the user manual for the specific multi-parameter sonde being used.

B. For quantitative field parameters measurement, use the weighted sensor guard to help protect the sensors and keep the sonde from moving during high-flow events.

C. Deploy the standardized sonde to the depth equal to the sample collection depth or other appropriate depth.

D. When collecting field measurements during groundwater sampling, use a flow-through cell for all parameters except turbidity. Measure the turbidity using a separate turbidimeter from the discharge of the flow-through cell.

E. Collect depth, temperature, DO, SC, pH, ORP, or turbidity measurement as determined by the sample plan. Refer to ENV-TI-05.80.42, Groundwater Sampling, for specific requirements related to field parameter measurements during groundwater sampling.

F. Allow the sonde to stabilize before collecting the values. Record the readings after five minutes of submersion if the parameter icon does not stabilize.

G. Record final, stabilized readings in the appropriate field logbook or field notebook as a backup to the Log File in the data logger.

H. Decontaminate the sonde after each deployment by following Section 6.5.1.

6.4 Collection of Field Measurements (continued)

I. Perform the post-monitoring (PM) standardization verification accuracy check for the same parameters the meter was initially standardized for, by repeating steps outlined in Section 6.3, without standardizing the instrument at the end of each day. Record the information in the CHECK FINAL section of the sonde's Attachment 3, Example - Field Standardization of Instruments, or equivalent.

J. Compare the initial and final measurements and use the standardization verification criteria in Section 6.3 to verify that the sonde remained within the acceptable accuracy range during use.

K. Immediately notify the TVA Project Manager by telephone and in writing if the instrument went out of standardization during field use.

6.5 Maintenance of Sonde

A. The sonde's Attachment 3, Example - Field Standardization of Instruments, maintenance logs, and associated electronic records provide a means of assessing the frequency of the routine maintenance for adequacy. Instruments and sensors taken out of service are tagged to indicate their status to prevent inadvertent use. Refer to the sonde's manual for maintenance considerations. Procedures for decontamination, standardization, and storage of the sonde are provided in this section.

B. The maintenance frequency of the sonde may be modified based on the comparison of AS FOUND and CHECK FINAL accuracy check measurements. The TVA Project Manager or Field Team Lead notifies the field crew if maintenance is needed or the frequency of maintenance needs to be modified.

6.5.1 Decontamination

A. Use DI water to rinse the probes after every deployment in the field. The sensors of the sonde should not be rinsed with alcohols or acid unless specified by the manufacturer. Individual probes may be rinsed with different solutions as specified by the manufacturer.

B. Paper towels and a tooth brush may be used to remove heavy solids accumulation on the sensors.

C. If needed, soak the sensors with non-phosphate-based detergent and water to remove biological, oil, or sediment buildup.

D. Refer to the ENV-TI-05.80.05, Field Sampling Equipment Cleaning and Decontamination. Dispose of investigation-derived wastes according to Section 6.6.

6.5.2 Factory Calibration

The factory calibration form, Traveler, for each sonde must accompany the particular unit.

A. Scan and store these traveler forms on a TVA network drive. The hardcopy is maintained in the field office where the units are stored.

B. Send the sonde for a factory Performance Test and Evaluation (PT&E) once per year, at a minimum. A completed PT&E form is returned with the sonde and is scanned and stored on a TVA network drive. The hardcopy continues to accompany the units and be stored near the units.

C. Maintain a schedule or calendar to confirm factory calibration history and needs.

6.5.3 Storage

It is imperative that the sonde is stored in an area where freezing will not occur and away from exposure to direct sunlight.

A. Store the sonde in accordance with the manufacture’s recommendations specified in the instrument owner’s manual. If the instrument owner’s manual specifies that the storage cup is to be filled with water, utilize clean potable water, unless otherwise directed by the owner’s manual. Do not use DI water for storage. If pH probes are left in DI water for prolonged periods, they are prone to malfunctioning.

B. Store the calibration solutions in accordance with the requirements of the product material safety data sheet (SDS) or the manufacturer’s instructions. Maintain a readily available SDS of each calibration solution near the standard solutions.

C. If possible, store the calibration solutions at the same temperature as the sonde to reduce the time for standardization.

6.6 Investigation-Derived Waste

Investigation-derived wastes, such as personal protective equipment (PPE), waste media, and decontamination fluids are managed in accordance with Table 3, Investigation-Derived Waste Stream. It is recommended to coordinate with appropriate facility personnel and arrange for disposal of investigation-derived waste based on results of analytical data or in accordance with the facility-specific waste management plan.

6.6 Investigation-Derived Waste (continued)

Investigation-Derived Waste Stream	Disposition Pathway
General refuse (such as paper, plastic bags, and cardboard)	Dispose as municipal trash or recycle as appropriate.
PPE (such as nitrile gloves and Tyvek®)	Dispose as municipal trash for routine activities. If expected to be contaminated with hazardous materials, containerize pending analytical results of associated samples.
Standardization solutions and decontamination fluids	Containerize in appropriate containers dependent on user's knowledge of the fluids or solutions and dispose appropriately based on analytical results.

Table 3, Investigation-Derived Waste Stream

6.7 Field Logbooks

A. Proper documentation of field activities is a crucial part of the field investigation and remediation process. Field work must be properly documented. Depending on the requirements of your organization, there are different mechanisms for recording. You must meet the requirements for your specific organization.

1. Electronic data collection system
2. Field logbooks
3. Field worksheets
4. Field notebooks
5. Data sheets

B. Detailed requirements for electronic data collection systems and tablets should be documented in a project specific data management plan or similar document.

C. Field logbooks and data sheets recording daily activities, including standardization activities and sample collection and tracking information, are maintained by the Field Team Lead or designee. Information is entered into the field logbook and data sheets by the appropriate field team member using indelible ink. In addition to the minimum requirements discussed in ENV-TI-05.80.03, Field Record Keeping, the field logbooks document those sampling characteristics specific to this TI and as defined in applicable sample planning documents.

6.7 Field Logbooks (continued)

D. Completed forms and field logbooks recording daily activities, including equipment standardization activities and sample collection and tracking information, are maintained by the Field Team Lead or designee in the field office. Information specific to each instrument is also maintained. This information includes, but is not limited to, manufacturer’s certificates of calibration including dates, results of adjustments, acceptance criteria, and due date of next calibration.

7.0 POST PERFORMANCE ACTIVITY

None

8.0 RECORDS

Records generated in the process of performing the activities in this TI must be processed and maintained as stated in the Environmental Records Matrix, in accordance with the TVA Document Services Records Management procedures.

8.1 Quality Assurance Records

A. Multi-parameter sonde standardization form

B. Multi-parameter sonde maintenance record

C. Multi-parameter sonde factory calibration sheets

D. Raw data files from sonde

E. Field and maintenance notebooks or logbooks

8.2 Non-Quality Assurance Records

None

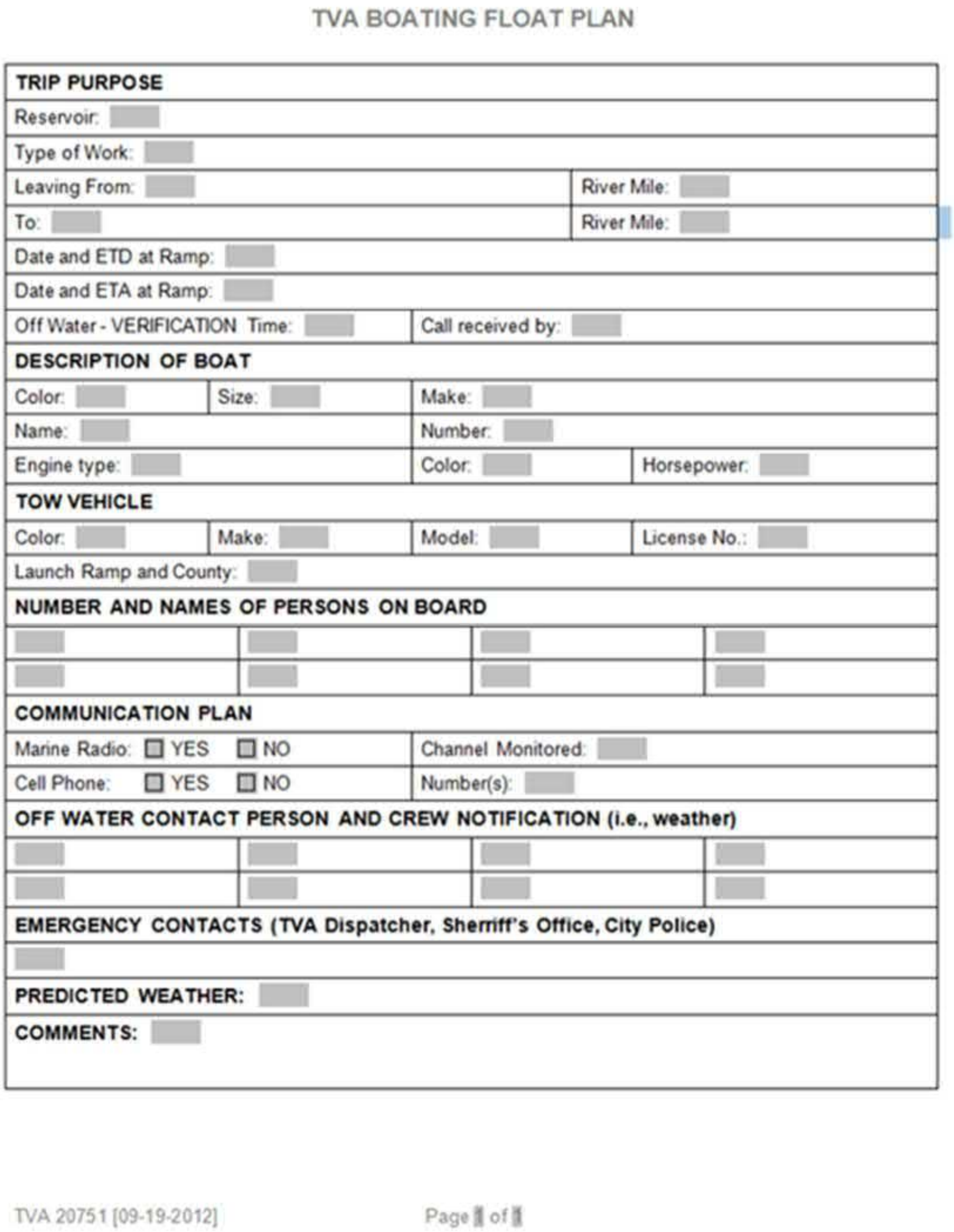
Attachment 1
(Page 1 of 1)

Recommended Multi-Parameter Sonde Equipment and Materials Checklist

Item Description	Check
Health & Safety	
Hard hat and steel-toed boots	
Hearing protection	
Non-powder latex or nitrile gloves	
Field first-aid kit and eye wash	
Safety glasses	
U.S. Coast Guard-approved flotation device, as needed	
Paperwork	
Multi-parameter sonde user manual	
JSA and PJB	
Project work and planning documents	
Location map, field data from previous events	
Field logbooks, data sheets and indelible ink pen/marker	
Multi-parameter sonde standardization forms (Attachment 3, Example - Field Standardization of Instruments) or equivalent	
Soil Sampling Equipment	
Multi-parameter sonde	
Data logger or recorder with the multi-parameter sonde and applicable cables	
Spare batteries	
Lab-supplied DI and potable water	
Cotton swabs	
KimWipes®, Task Wipers, or equivalent	
Tool kit	
Additional items recommended by instrument manufacturer	
NIST-traceable thermometer (non-mercury)	
Bucket	
Aquarium-grade pump and filter	
NIST-traceable pH buffer solutions (pH 4, 7, and/or 10)	
Zobell's and/or Quinhydrone solution and 1N HCl solution	
Conductivity standard solutions (100 μS/cm, 500 μS/cm, or other standards)	
Turbidity standard solutions (<0.1, 100, 400, and 3,000 NTU or other standards)	

Attachment 2
(Page 1 of 1)

Example - TVA Boating Float Plan



TVA BOATING FLOAT PLAN

TRIP PURPOSE

Reservoir:

Type of Work:

Leaving From: River Mile:

To: River Mile:

Date and ETD at Ramp:

Date and ETA at Ramp:

Off Water - VERIFICATION Time: Call received by:

DESCRIPTION OF BOAT

Color: Size: Make:

Name: Number:

Engine type: Color: Horsepower:

TOW VEHICLE

Color: Make: Model: License No.:

Launch Ramp and County:

NUMBER AND NAMES OF PERSONS ON BOARD

COMMUNICATION PLAN

Marine Radio: ☐ YES ☐ NO Channel Monitored:

Cell Phone: ☐ YES ☐ NO Number(s):

OFF WATER CONTACT PERSON AND CREW NOTIFICATION (i.e., weather)

EMERGENCY CONTACTS (TVA Dispatcher, Sherriff's Office, City Police)

PREDICTED WEATHER:

COMMENTS:

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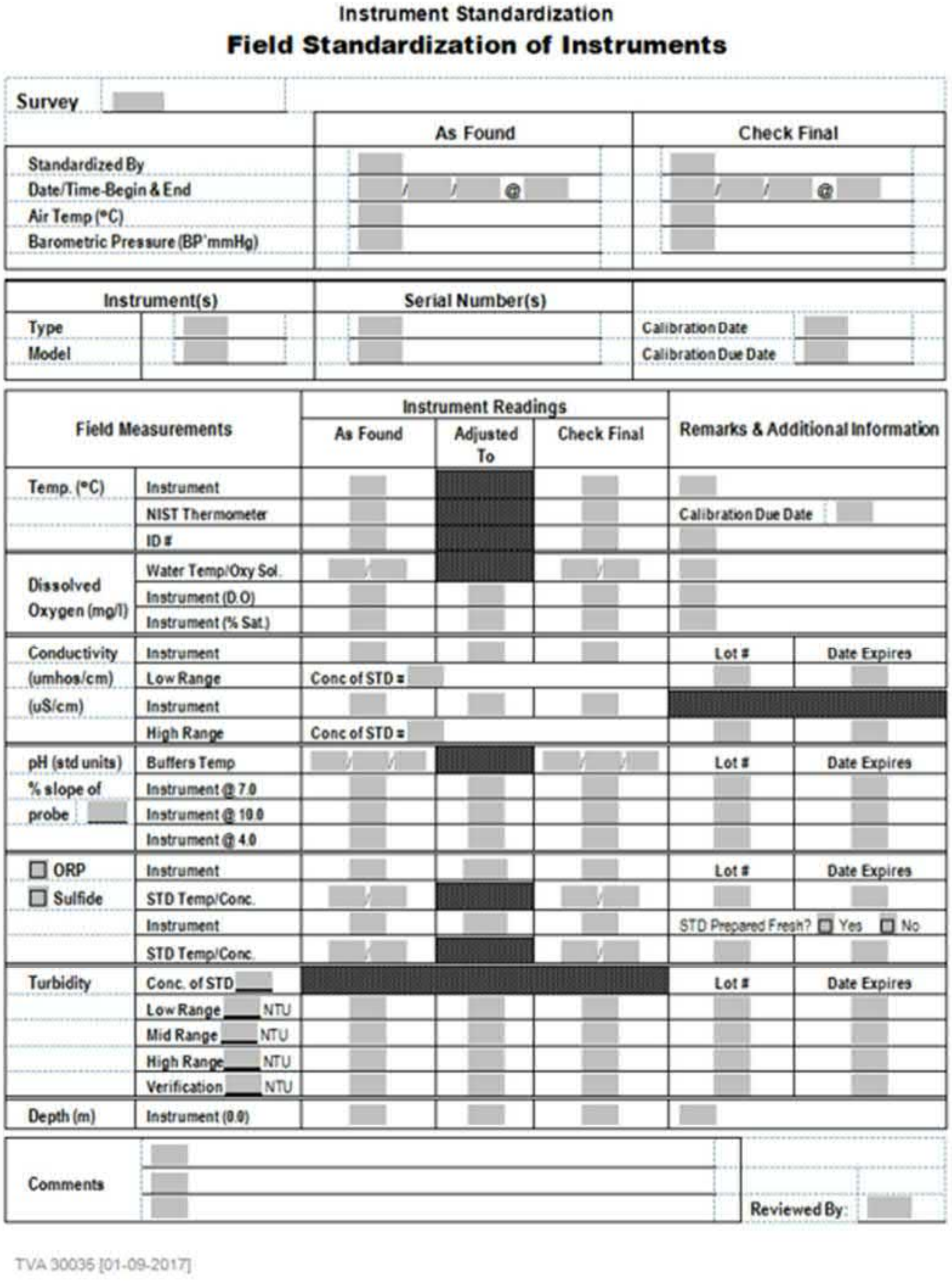
Attachment 3
(Page 1 of 1)

Example - Field Standardization of Instruments



Instrument Standardization

Field Standardization of Instruments

Survey

	As Found	Check Final
Standardized By		
Date/Time-Begin & End	/ / @	/ / @
Air Temp (°C)		
Barometric Pressure (BP"mmHg)		

Instrument(s)		Serial Number(s)		
Type			Calibration Date	
Model			Calibration Due Date	

Field Measurements		Instrument Readings			Remarks & Additional Information	
		As Found	Adjusted To	Check Final		
Temp. (°C)	Instrument					
	NIST Thermometer				Calibration Due Date	
	ID #					
Dissolved Oxygen (mg/l)	Water Temp/Oxy Sol.	/		/		
	Instrument (D.O)					
	Instrument (% Sat.)					
Conductivity (umhos/cm) (uS/cm)	Instrument				Lot #	Date Expires
	Low Range	Conc of STD =				
	Instrument					
	High Range	Conc of STD =				
pH (std units) % slope of probe	Buffers Temp	/ /		/ /	Lot #	Date Expires
	Instrument @ 7.0					
	Instrument @ 10.0					
	Instrument @ 4.0					
☐ ORP ☐ Sulfide	Instrument				Lot #	Date Expires
	STD Temp/Conc.	/		/		
	Instrument				STD Prepared Fresh? ☐ Yes ☐ No	
	STD Temp/Conc.	/		/		
Turbidity	Conc. of STD				Lot #	Date Expires
	Low Range NTU					
	Mid Range NTU					
	High Range NTU					
	Verification NTU					
Depth (m)	Instrument (0.0)					

Comments

Reviewed By:

TVA 30036 [01-09-2017]

Iron, Ferrous, Test Kit

IR-18C (2667200)

DOC326.97.00063

Test preparation

CAUTION: ⚠ ***Review the Safety Data Sheets (MSDS/SDS) for the chemicals that are used. Use the recommended personal protective equipment.***

- Analyze samples immediately after collection.
- Put the color disc on the center pin in the color comparator box (numbers to the front).
- Use the indoor light color disc when the light source is fluorescent light. Use the outdoor light color disc when the light source is sunlight.
- Rinse the tubes with sample before the test. Rinse the tubes with deionized water after the test.
- If the color match is between two segments, use the value that is in the middle of the two segments.
- If the color disc becomes wet internally, pull apart the flat plastic sides to open the color disc. Remove the thin inner disc. Dry all parts with a soft cloth. Assemble when fully dry.
- Undissolved reagent does not have an effect on test accuracy.
- To verify the test accuracy, use a standard solution as the sample.
- This test kit measures ferrous iron. To determine ferric iron (Fe^{3+}), subtract the ferrous iron result from a total iron test.

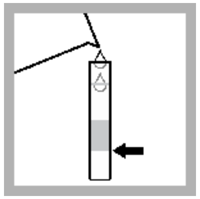
Replacement items

Description	Unit	Item no.
Ferrous Iron Reagent Powder Pillows	100/pkg	103769
Color disc, iron, indoor light, 0–7 mg/L	each	9261000
Color disc, iron, outdoor light, 0–7 mg/L	each	9263700
Color comparator box	each	173200
Plastic viewing tubes, 18 mm, with caps	4/pkg	4660004
Vial with 2, 5, 10, 15, 20 and 25-mL marks	each	219300

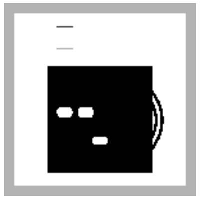
Optional items

Description	Unit	Item no.
Caps for plastic viewing tubes (4660004)	4/pkg	4660014
Glass viewing tubes, glass, 18 mm	6/pkg	173006
Stoppers for 18-mm glass tubes and AccuVac Ampuls	6/pkg	173106
Water, deionized	500 mL	27249

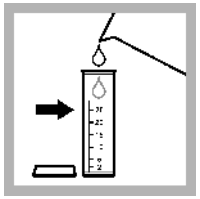
Test procedure—Iron, ferrous (0–7 mg/L Fe^{2+})



1. Fill a tube to the first line (5 mL) with sample.

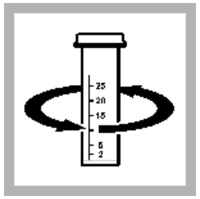


2. Put the tube into the left opening of the color comparator box.



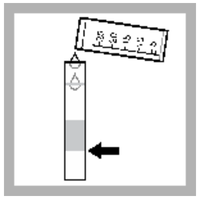
3. Fill the vial to the 25-mL mark with sample.

4. Add one Ferrous Iron Reagent Powder Pillow to the vial.

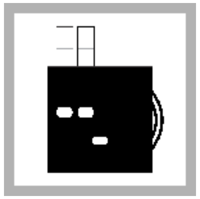


5. Swirl to mix. A orange color develops if ferrous iron is in the sample.

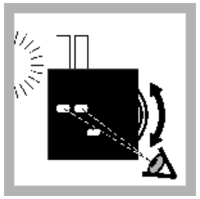
6. Wait 3 minutes.



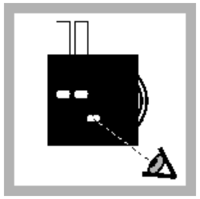
7. Fill a second tube to the first line (5 mL) with the prepared sample.



8. Put the second tube into the color comparator box.



9. Hold the color comparator box in front of a light source. Turn the color disc to find the color match.



10. Read the result in mg/L in the scale window.

12/2015, Edition 1

Sulfide

DOC316.53.01136

USEPA[1] Methylene Blue Method[2]

Method 8131

5 to 800 µg/L S^{2-} (spectrophotometers)

Reagent Solution

0.01 to 0.70 mg/L S^{2-} (colorimeters)

Scope and application: For testing total sulfides, H_2S, HS^-, and certain metal sulfides in groundwater, wastewater, brines and seawater.

[1] USEPA accepted for reporting wastewater analysis. Procedure is equivalent to Standard Method 4500-S^{2-} D.

[2] Adapted from Standard Methods for the Examination of Water and Wastewater.

Test preparation

Instrument-specific information

Table 1 shows all of the instruments that have the program for this test. The table also shows sample cell and orientation requirements for reagent addition tests, such as powder pillow or bulk reagent tests.

To use the table, select an instrument, then read across to find the applicable information for this test.

Table 1 Instrument-specific information

Instrument	Sample cell orientation	Sample cell
DR 6000 DR 3800 DR 2800 DR 2700 DR 1900	The fill line is to the right.	2495402 
DR 5000 DR 3900	The fill line is toward the user.	
DR 900	The orientation mark is toward the user.	2401906 

Before starting

Samples must be analyzed immediately after collection and cannot be preserved for later analysis.
Install the instrument cap on the DR 900 cell holder before ZERO or READ is pushed.
Some sulfide loss can occur if dilution is necessary.
Review the Safety Data Sheets (MSDS/SDS) for the chemicals that are used. Use the recommended personal protective equipment.
Dispose of reacted solutions according to local, state and federal regulations. Refer to the Safety Data Sheets for disposal information for unused reagents. Refer to the environmental, health and safety staff for your facility and/or local regulatory agencies for further disposal information.

Items to collect

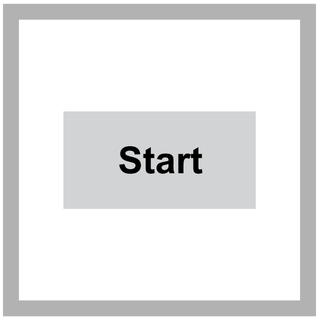
Description	Quantity
Sulfide 1 Reagent	1–2 mL
Sulfide 2 Reagent	1–2 mL
Water, deionized	10–25 mL
Pipet, serological, 10-mL	1
Pipet Filler, safety bulb	1
Sample cells (For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.)	2
Stoppers	2

Refer to Consumables and replacement items on page 5 for order information.

Sample collection

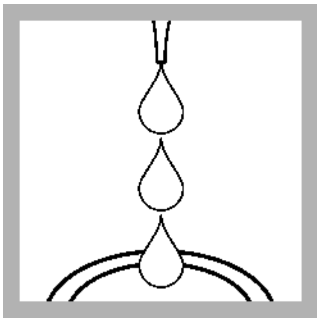
- Analyze the samples immediately. The samples cannot be preserved for later analysis.
- Collect samples in clean glass or plastic bottles with tight-fitting caps. Completely fill the bottle and immediately tighten the cap.
- Prevent agitation of the sample and exposure to air.

Reagent solution procedure

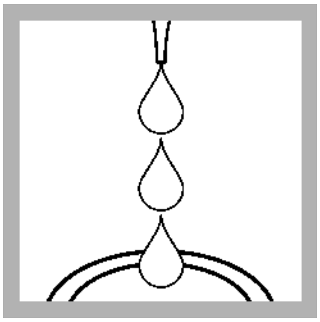


1. Start program **690 Sulfide**. For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.

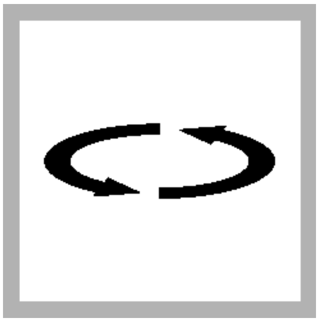
2. Prepare the blank: Fill a sample cell with deionized water. Use 10 mL for spectrophotometers and 25 mL for colorimeters.



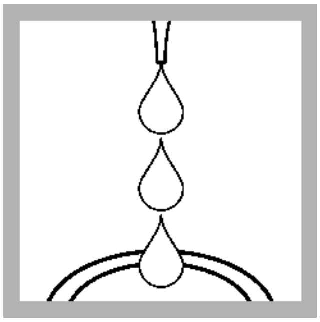
3. Prepare the sample: Use a pipet to add sample to a second sample cell. Use 10 mL for spectrophotometers and 25 mL for colorimeters. Do not mix the sample more than necessary to prevent sulfide loss.



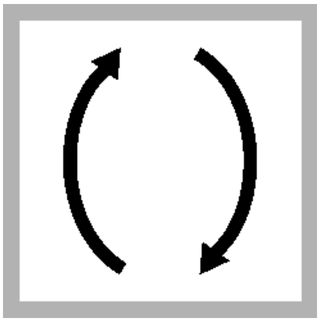
4. Add Sulfide 1 Reagent to each sample cell. Use 0.5 mL for spectrophotometers and 1.0 mL for colorimeters.



5. Swirl to mix.

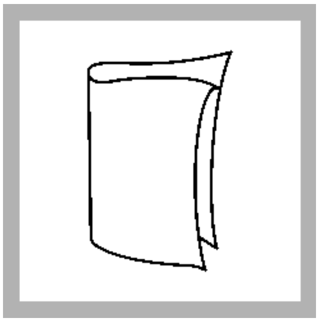


6. Add Sulfide 2 Reagent to each sample cell. Use 0.5 mL for spectrophotometers and 1.0 mL for colorimeters.

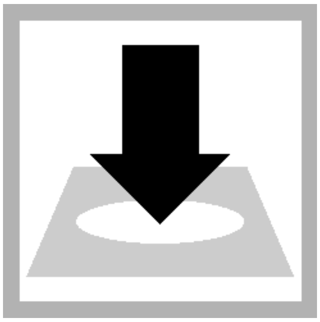


7. Close the sample cell. Invert the sample cell to mix. A pink color will develop initially. If sulfide is present, the solution becomes blue.

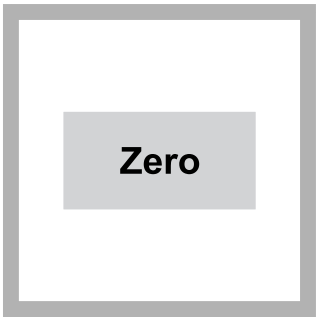
8. Start the instrument timer. A five-minute reaction time starts.



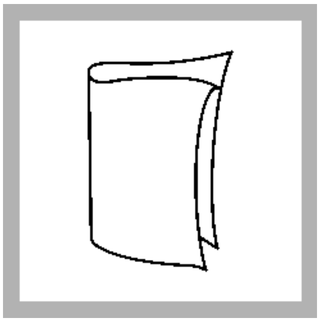
9. When the timer expires, clean the blank sample cell.



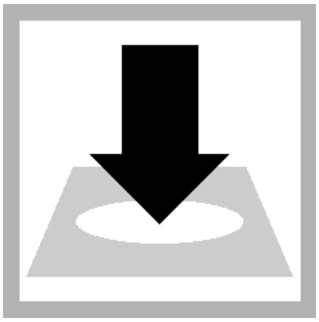
10. Insert the blank into the cell holder.



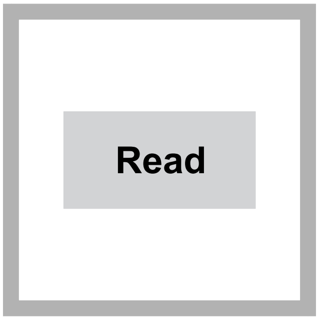
11. Push **ZERO**. The display shows 0 µg/L or 0.00 mg/L S^{2-}.



12. Clean the prepared sample cell.



13. Insert the prepared sample into the cell holder.



14. Push **READ**. Results show in µg/L or mg/L S^{2-}.

Soluble sulfides

To measure soluble sulfides, use a centrifuge to separate the solids. To make an estimate of the amount of insoluble sulfides in the sample, subtract the soluble sulfide concentration from the total (with solids) sulfide concentration.

1. Fill a centrifuge tube completely with sample and immediately cap the tube.
2. Put the tube in a centrifuge and run the centrifuge to separate the solids.
3. Use the supernatant as the sample in the test procedure.

Interferences

Interfering substance	Interference level
Barium	Concentrations more than 20 mg/L barium react with the sulfuric acid in Sulfide 1 Reagent and form a $BaSO_4$ (barite) precipitate. To correct for this interference: **1.** Dilute the sample in the test procedure as follows: • Spectrophotometers: use a 0.1-mL or 1.0-mL sample volume and add deionized water to the 10-mL mark. • Colorimeters: use a 0.25-mL or 2.5-mL sample volume and add deionized water to the 25-mL mark. **2.** Add both Sulfide 1 and Sulfide 2 reagents per the procedure steps. **3.** After the 5-minute reaction period, pour the sample into a 50-mL beaker. **4.** Pull the sample into a Luer-Lock syringe (10 cc for spectrophotometers or 60 cc for colorimeters). **5.** Put a 0.45-µm filter disc on the Luer-Lock tip and filter the sample into a clean sample cell for measurement. Use deionized water to prepare the blank. **6.** Set the instrument zero and read the result, per the procedure steps. **7.** Multiply by the appropriate dilution factor for the dilution used (10 or 100).
Strong reducing substances such as sulfite, thiosulfate and hydrosulfite	Prevent the full color development or reduce the blue color
Sulfide, high levels	High concentrations of sulfide can inhibit the full color development. Use a diluted sample in the test procedure. Some sulfide loss can occur when the sample is diluted.
Turbidity	Pre-treat the sample to remove sulfide, then use the pre-treated sample as the blank in the test procedure. Prepare a sulfide-free blank as follows: **1.** Measure 25 mL of sample into a 50-mL Erlenmeyer flask. **2.** Add 30-g/L Bromine Water by drops with constant swirling until a yellow color remains. **3.** Add 30-g/L Phenol Solution by drops with constant swirling until the yellow color is removed. **4.** Use this solution to replace the deionized water blank in the test procedure.

Method performance

The method performance data that follows was derived from laboratory tests that were measured on a spectrophotometer during ideal test conditions. Users can get different results under different test conditions.

Program	Standard	Precision (95% confidence interval)	Sensitivity Concentration change per 0.010 Abs change
690	520 µg/L S^{2-}	504–536 µg/L S^{2-}	5 µg/L S^{2-}

Summary of method

Hydrogen sulfide and acid-soluble metal sulfides react with N,N-dimethyl-p-phenylenediamine sulfate to form methylene blue. The intensity of the blue color is proportional to the sulfide concentration. High sulfide levels in oil field waters may be determined after proper dilution. The measurement wavelength is 665 nm for spectrophotometers or 610 nm for colorimeters.

Pollution prevention and waste management

Reacted samples contain hexavalent chromium and must be disposed of as a hazardous waste. Dispose of reacted solutions according to local, state and federal regulations.

Consumables and replacement items

Required reagents

Description	Quantity/test	Unit	Item no.
Water, deionized	varies	4 L	27256
Sulfide Reagent Set	—	—	2244500
Includes:			
Sulfide 1 Reagent	1–2 mL	100 mL MDB	181632
Sulfide 2 Reagent	1–2 mL	100 mL MDB	181732

Required apparatus

Description	Quantity/test	Unit	Item no.
Pipet, serological, graduated, 10 mL	1	each	53238
Pipet filler, safety bulb	1	each	1465100
Stoppers for 18-mm tubes and AccuVac Ampuls	2	6/pkg	173106

Optional reagents and apparatus

Description	Unit	Item no.
Bromine Water, 30-g/L	29 mL	221120
Phenol Solution, 30-g/L	29 mL	211220
Stoppers for 18-mm tube	25/pkg	173125
Flask, Erlenmeyer, 50 mL	each	50541

FOR TECHNICAL ASSISTANCE, PRICE INFORMATION AND ORDERING:
In the U.S.A. – **Call toll-free 800-227-4224**
Outside the U.S.A. – **Contact the HACH office or distributor serving you.**
On the Worldwide Web – **www.hach.com**; E-mail – **techhelp@hach.com**

HACH COMPANY
WORLD HEADQUARTERS
Telephone: (970) 669-3050
FAX: (970) 669-2932

09/2018, Edition 11

Carbon Dioxide Test Kit

1.25 to 25 mg/L, 2 to 40 mg/L, 5 to 100 mg/L CO_2

For test kit 143601 (CA-23)

DOC326.98.00004

Additional copies available on www.hach.com

Test preparation

- Rinse labware with deionized water between tests.
- When titrating, count each drop of titrant. Hold the dropper vertically. Swirl after each drop is added.

CAUTION: Handle chemical standards and reagents carefully. Review Material Safety Data Sheets for safe handling, storage and disposal information.

Required items

Description	Unit	Catalog no.
Measuring Tube	each	43800
Mixing Bottle	6/pkg	232706
Phenolphthalein Indicator Solution	15 mL (½ oz) SCDB[1]	189736
Sodium Hydroxide Solution, 0.01 N	100 mL MDB[2]	67132

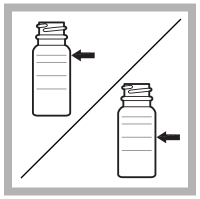
[1] Self-contained dropping bottle

[2] Marked dropping bottle

Optional items

Description	Unit	Catalog no.
Deionized Water	500 mL	27249

Low range (1.25 to 25 mg/L) and medium range (2 to 40 mg/L) test procedure

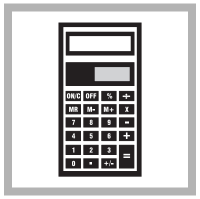


1. Low Range: Fill the bottle to the 23-mL mark with sample.

Medium Range: Fill the bottle to the 15-mL mark with sample.

2. Add one drop of Phenolphthalein Indicator Solution.

3. Add Sodium Hydroxide Solution by drops. Count the drops until the color changes to light pink and persists for 30 seconds. Swirl to mix after each drop.



4. Low Range: Calculate the result. Each drop of Sodium Hydroxide Solution used in step 3 equals 1.25 mg/L carbon dioxide (CO_2).

Medium Range: Calculate the result. Each drop of Sodium Hydroxide Solution used in step 3 equals 2 mg/L carbon dioxide (CO_2).

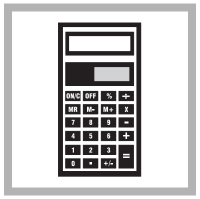
High range (5 to 100 mg/L) test procedure

1. Fill the plastic tube to the top with sample.

Pour the sample into the bottle.

2. Add one drop of Phenolphthalein Indicator Solution.

3. Add Sodium Hydroxide Solution by drops. Count the drops until the color changes to light pink and persists for 30 seconds. Swirl to mix after each drop.



4. Calculate the result. Each drop of Sodium Hydroxide Solution used in step 3 equals 5 mg/L carbon dioxide (CO_2).

For technical assistance or ordering information: visit www.hach.com, call 800-227-4224 or email techhelp@hach.com

Edition 1, August 2006

二氧化碳测试工具包

1.25 至 25 mg/L， 2 至 40 mg/L， 5 至 100 mg/L CO$_2$

适用于测试工具包 143601 (CA-23) DOC326.98.00004

www.hach.com 上提供的其他副本

测试准备

- 在进行新的测试之前使用去离子水清洗实验室器具。
- 滴定时，对每一滴滴定剂都要计数。垂直握住滴管。每加一滴都要摇匀。

警告：处理化学标准溶液和试剂时要小心。有关安全处理、存储和处置的信息，请查阅材料安全数据表。

必需项目

说明	单位	货号
量筒	个	43800
混合瓶	6/pkg	232706
酚酞指示剂溶液	15 mL (½ oz) SCDB[1]	189736
0.01 N 的氢氧化钠溶液	100 mL MDB[2]	67132

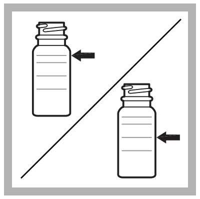
[1] 独立点滴瓶

[2] 有标记的点滴瓶

可选项目

说明	单位	货号
去离子水	500 mL	27249

低量程 （1.25 至 25 mg/L）和中量程 （2 至 40 mg/L）测试步骤

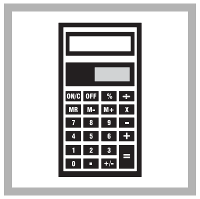


1. 低量程：将取样倒入瓶中至 23-mL 标记处。

中量程：
将取样倒入瓶中至
15-mL 标记处。

2. 加入一滴酚酞指示剂溶液。

3. 逐滴滴加氢氧化钠溶液。数一下颜色变为淡粉色并持续 30 秒时滴入的滴数。每加一滴都要摇匀。



4. 低量程：计算结果。在步骤 3 中使用的每一滴氢氧化钠溶液相当于1.25 mg/L 的二氧化碳 (CO$_2$)。

中量程：计算结果。在步骤 3 中使用的每一滴氢氧化钠溶液相当于 2 mg/L 的二氧化碳 (CO$_2$)。

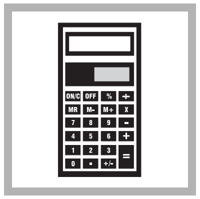
高量程 （5 至 100 mg/L）测试步骤

1. 将取样加入塑料试管中至顶部。

将取样倒入瓶中。

2. 加入一滴酚酞指示剂溶液。

3. 逐滴滴加氢氧化钠溶液。数一下颜色变为淡粉色并持续 30 秒时滴入的滴数。每加一滴都要摇匀。



4.计算结果。在步骤 3 中使用的每一滴氢氧化钠溶液相当于 5 mg/L 二氧化碳 (CO$_2$)。

若要获取技术帮助或订购信息，请访问 www.hach.com，致电 800-227-4224 或发送电子邮件至 techhelp@hach.com

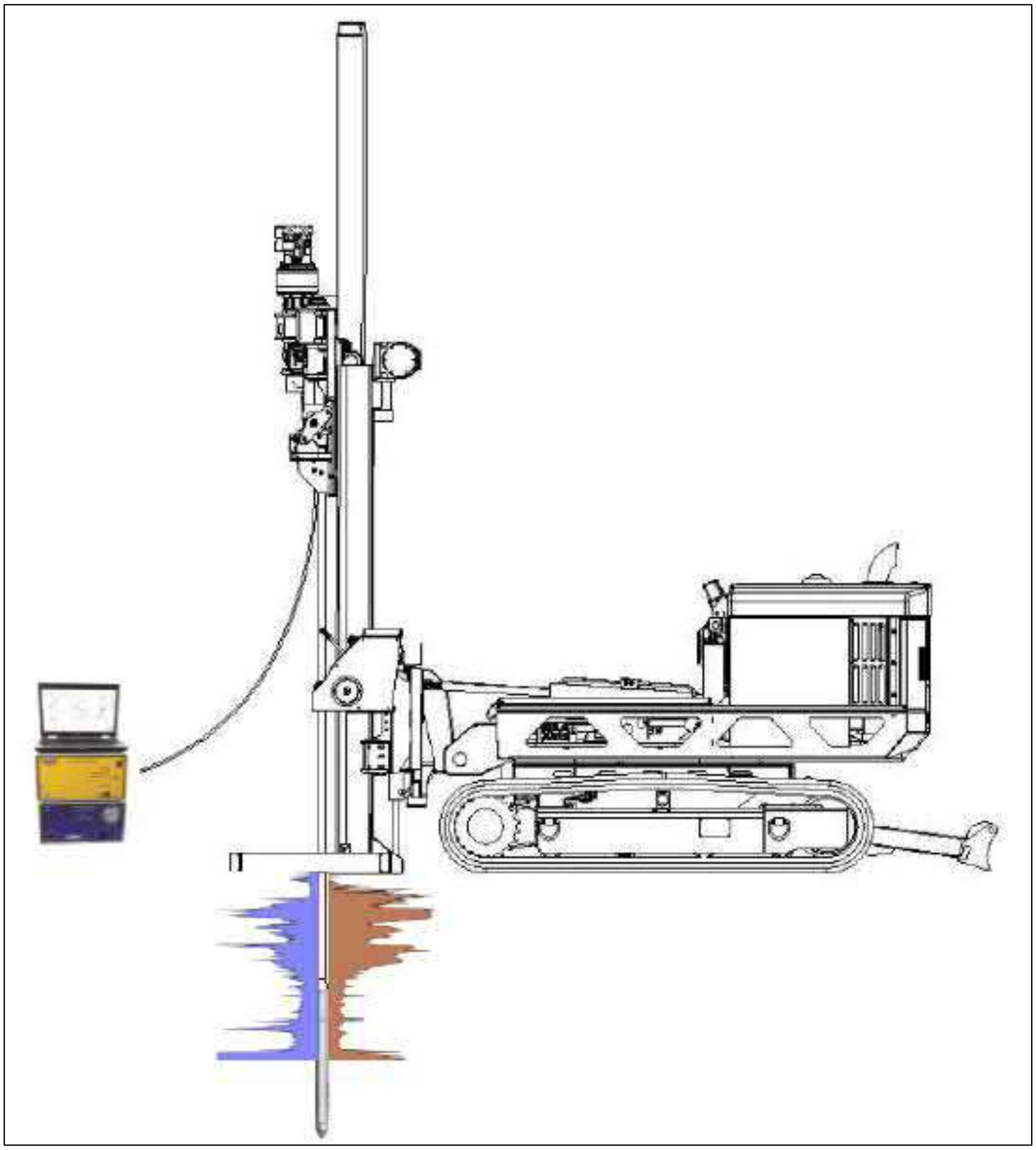
2006 年 8 月第 1 版

Geoprobe® Hydraulic Profiling Tool (HPT) System

Standard Operating Procedure

Technical Bulletin No. MK3137

Prepared: January 2015



1.0 Objective

This document serves as the standard operating procedure for the Geoprobe® Hydraulic Profiling Tool (HPT) system. In this procedure, the HPT system is used to measure the pressure response of soil to injected water for identifying potential flow paths and to assist with characterization of soil type.

2.0 Background

2.1 Definitions

Geoprobe®*: A brand of high quality, hydraulically-powered machines that utilize both static force and percussion to advance sampling and logging tools into the subsurface. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform soil core and soil gas sampling, groundwater sampling and testing, electrical conductivity and contaminant logging, grouting, and materials injection.

**Geoprobe® and Geoprobe Systems® are registered trademarks of Kejr, Inc., Salina, Kansas.*

Hydraulic Profiling Tool (HPT) System: A system manufactured by Geoprobe Systems® to evaluate the hydraulic behavior of subsurface soil. The tool is advanced through the subsurface at a constant rate while water is injected through a screen on the side of the probe. An in-line pressure sensor measures the pressure response of the soil to water injection. The pressure response identifies the relative ability of a soil to transmit water. Both pressure and flow rate are logged versus depth.

2.2 Introduction

The HPT system has been developed by Geoprobe Systems® for the geohydrologic characterization of soils. The HPT probe and logging system is able to quickly provide logs that are easily interpreted. HPT logs are used to indicate hydraulic conductivity, EC, hydrostatic profile, and areas of EC/permeability anomalies.

The HPT system is designed to evaluate the hydraulic behavior of unconsolidated materials. As the probe is pushed or hammered at 2cm/s, clean water is pumped through a screen on the side of the HPT probe at a low flow rate, usually less than 300mL/min. Injection pressure, which is monitored and plotted with depth, is an indication of the hydraulic properties of the soil. That is, a low pressure response would indicate a relatively large grain size, and the ability to easily transmit water. Conversely, a high HPT pressure response would indicate a relatively small grain size and the lack of ability to transmit water.

An electrical conductivity measurement array is built into the HPT probe. This allows the user to collect soil electrical conductivity (EC) data for lithologic interpretation. In general, the higher the electrical conductivity value, the smaller the grain size, and vice versa. However, other factors can affect EC, such as mineralogy and pore water chemistry (brines, extreme pH, contaminants). In contrast, HPT pressure response is independent of these chemical and mineralogical factors.

There are four primary components of the HPT system: the probe assembly, trunkline, HPT Flow Controller (K6300 Series), and Field Instrument (FI6000 series). These primary components are shown in Figure 2.1.

The probe assembly consists of the HPT probe and connection section. This assembly houses the downhole HPT pressure transducer, water and electrical connections, and the probe body with the injection screen and electrical conductivity array.

Injecting water at a constant rate is integral to system operation. The HPT Flow Module houses the pump and associated hand crank mechanism used for adjusting the output flow of the HPT pump. The flow module also contains the HPT flow measurement and injection line pressure transducers. HPT flow can be adjusted from approximately 50 to 500ml/min. The HPT pump is a positive displacement pumping device with minimal decrease in flow over the HPT operating pressure range. The flow module is equipped with an internal bypass that is factory set to open and return flow to the supply reservoir at a pressure of 120psi. When the soil resistance to water injection becomes sufficiently great, the HPT Flow Module bypass will open, returning some or all of the pumped flow to the supply reservoir. The flow meter only measures flow leaving the module to the HPT probe. The HPT Flow Module is connected to the Field Instrument via a data cable.

Water and power are transmitted from the controller to the probe assembly via the HPT trunkline. The probe rods must be pre-strung with the trunkline before advancing the probe.

Data collection occurs in real time by connecting the controller to the field instrument. The field instrument collects, stores and displays transducer pressure, flow rate and electrical conductivity, line pressure, probe rate, and diagnostic parameters, with depth via the field laptop.

Since the HPT pressure response is analogous to the soil's ability to transmit water (and therefore the to the soil's dominant grain size), the HPT system can be used to identify potential contaminant migration pathways. Similarly, it can help identify zones for remedial material injection or provide qualitative guidance on how difficult injection may be in different zones of the formation.

The HPT system may be used to direct other investigation methods, such as soil and groundwater sampling and slug testing. HPT pressure response and EC data can help target zones of geologic and hydraulic interest, minimizing the number of soil and groundwater samples required to adequately develop a site conceptual model. When hydraulic conductivity values are required, the

HPT system can also help the user identify zones to slug test, as well as the length of the screen required to adequately test the zone.

The HPT system also can be used to collect static water pressure data at discrete intervals during the logging process. These static pressure data can be used to calculate static water levels or to create a hydrostatic profile for the log.

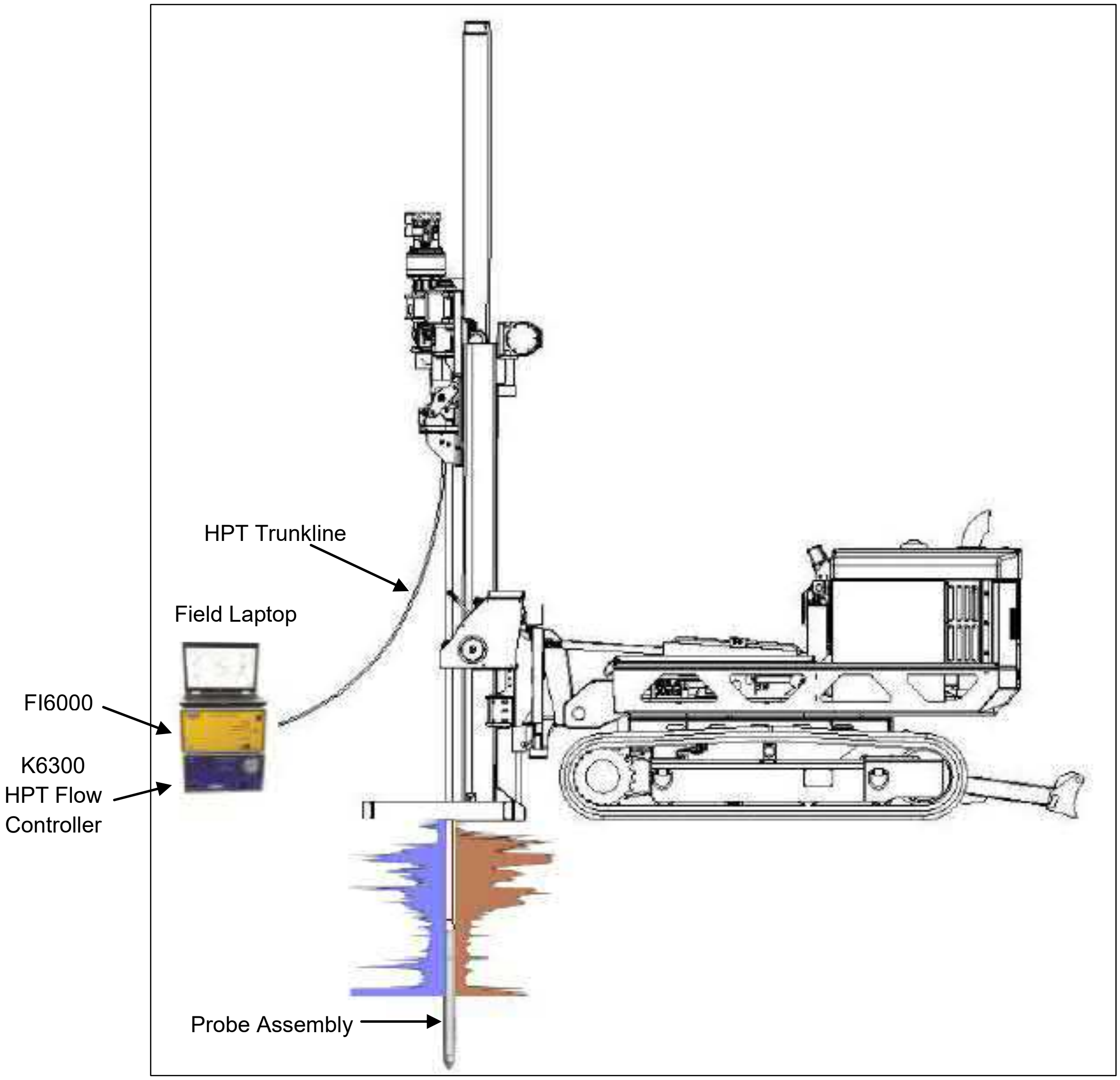


Figure 2.1: HPT Components

3.0 Tools and Equipment

The following equipment is required to perform and record an HPT log using a Geoprobe® 66- or 78-Series Direct Push Machine. Refer to Appendix I for identification of the specified parts.

Basic HPT System Components	Quantity	Material Number
Field Instrument, 120V (Model FI6000)	-1-	213940
Field Instrument, 220V (Model FI6003)	*	213941
HPT Acquisition Software	-1-	214128
HPT Flow Module, 120V (Model K6300)	-1-	214091
HPT Flow Module, 220V (Model K6303)	*	214093
HPT Probe, 1.75 inch	-1-	215667
MIP/HPT Connection Tube	-1-	206304
MIP/HPT Adapter 1.5 Pin x LB Box	-1-	203794
MIP/HPT Adapter 1.75ML Pin x LB Box	**	220966
HPT Probe, 2.25 inch	**	214097
2.25 Connection Tube	**	219455
2.25 Inch Water Seal Drive Head	**	212089
2.75 Inch Water Seal Drive Head	**	209796
HPT Reference Tube 1.75 in HPT Probe	-1-	212689
HPT Reference Tube 2.25 in HPT Probe	**	211762
HPT Trunkline 150 ft.	-1-	214095
HPT Trunkline 200 ft.	(optional)	214096
HPT Service Kit	-1-	205599
HPT Test Load	-1-	206552
EC Probe Test Jig	-1-	214237
EC Test Load	-1-	*208075*
EC Bypass Cable	-1-	204025
Stringpot, 100-inch	-1-	214227
Stringpot Cordset, 65-feet (19.8 m)	-1-	202884

*Use in place of 120V components if desired.

**Use in place of 1.75 inch probe and components if desired.

4.0 HPT Assembly

Refer to Appendix I

Threading the Rods

- Protect the end of the trunkline to be threaded through the rods with electrical tape or shrink tubing.
- Probe rods must alternate directions prior to threading the trunkline.
- The end of the HPT trunkline with chrome connectors is the downhole or probe end.
- The probe end of the trunkline will always enter the male end and exit the female end of the probe rods.
- The instrument end (no chrome connectors) will always enter the female end and exit the male end of the probe rods.
- After the trunkline is through the probe rods make sure the downhole end is threaded through the male end of the drive head and connection tube prior to connecting to the probe.
- The trunkline is now ready to connect to the instrument and HPT pressure sensor and probe.

5.0 Field Operation

5.1 Instrument Setup

1. Connect the HPT Controller (K6300), Field Instrument (FI6000) and laptop (Fig. 5.1) to an appropriate power source.

2. Connect the FI6000 to the K6300 using the 62-pin serial cable inserted into the acquisition port of each instrument.

3. Secure the EC wires into the Green terminal block connector and insert into the FI6000. The wires match to the EC dipoles in the following top down order when the probe tip is on the ground – white, black, yellow and blue (Fig 5.2).

Figure 5.1: HPT Instrument Setup

4. Secure the HPT sensor wires to the appropriate inputs on the green terminal block connector and connect to the rear of the K6300. The top down order of the wires which is listed on the back of the instrument is: brown, orange, red and reserved (open).

5. Insert the nylon water line tubing from the trunkline into the water output connector on the back of the K6300.

6. Connect the HPT water supply hose into the input port on the rear of the K6300 and insert the filtered end of the supply line into a water supply tank. The bypass line connects to the bypass port and will follow the supply line back to the supply tank.

7. Connect the USB cable between the USB interface port on the rear of the FI6000 to USB input on the field laptop computer.

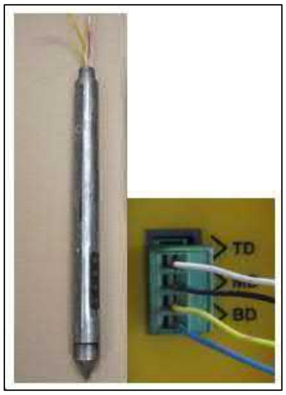


Figure 5.2: EC Wire Connections

8. A stringpot is required to measure depth. Bolt the stringpot onto the machine and the stringpot onto the bracket. Connect the plastic connector end of the stringpot cable to the "Stringpot" connector on the back of the Field Instrument and the metal connector to the stringpot. Pull the stringpot cable and attach to the stringpot piston weight which should be mounted to the probe machine foot and pull the keeper pin so the weight is free to move.

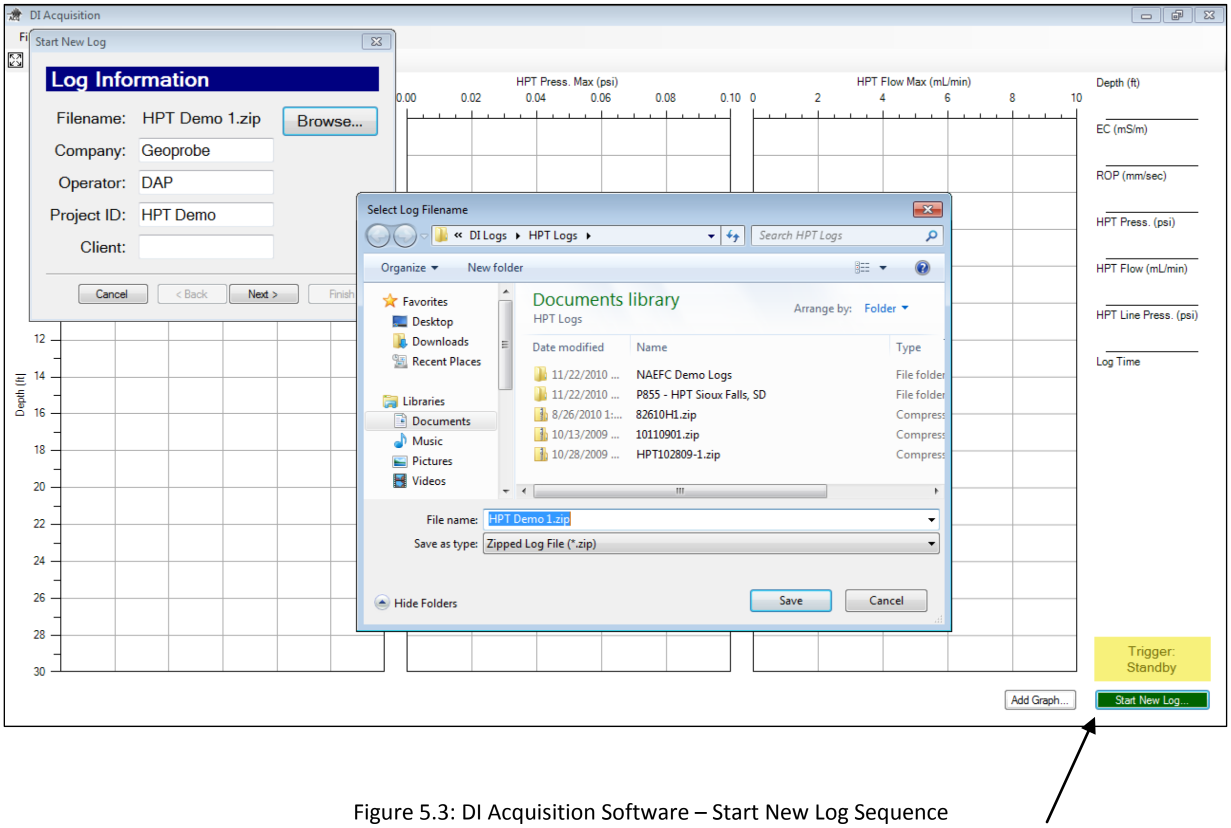
5.2 Starting the Software

1. Make sure the FI6000 and K6300 are connected together with the 62 pin cable, powered on and connected to the computer by the USB cable for the software to load properly.

2. Start the DI Acquisition Software which should open in HPT mode.

3. Select "Start New Log". The software will request log information and have you browse for a storage location and create and save a file name for the log (Fig. 5.3).

4. Select "Next". If the software has been run before it will show a list of previous settings including Probe Type, EC Configuration, Stringpot length, rod length and HPT Transducer. If any of these have changed or you are unsure select "No" but if they are all the same select "yes". If you select "No" the software will have you select the proper settings after the EC Load Test, if you selected "Yes" the selection of these settings will be bypassed.



Filename: HPT Demo 1.zip
Company: Geoprobe
Operator: DAP
Project ID: HPT Demo
Client:

Date modified	Name	Type
11/22/2010 ...	NAEFC Demo Logs	File folder
11/22/2010 ...	P855 - HPT Sioux Falls, SD	File folder
8/26/2010 1:...	82610H1.zip	Compress
10/13/2009 ...	10110901.zip	Compress
10/28/2009 ...	HPT102809-1.zip	Compress

File name: HPT Demo 1.zip
Save as type: Zipped Log File (*.zip)

Figure 5.3: DI Acquisition Software – Start New Log Sequence

5.3 QA Testing the EC and HPT Systems

Both the EC and HPT components must be tested before and after each log. This is required to ensure that the equipment is working properly and capable of generating good data before and after the log.

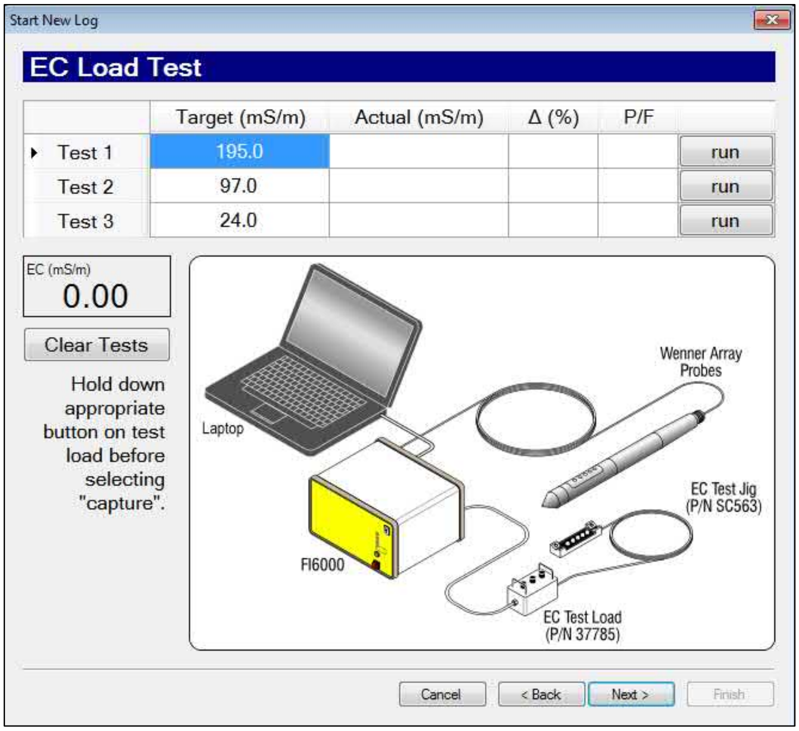
A. Electrical Conductivity Load Test

1. Secure the EC 3 position test load connector (208075) to the test input jack on the back of the Field Instrument.

2. Secure the EC Probe Test Jig into the input on the EC 3 position test load.

3. Clean and dry the EC dipoles as well as several inches of the probe body above the pins.

4. Place the EC Test Jig (214237) so that the four springs on the test jig touch the four dipoles of the Wenner EC array (Fig. 5.4). Make sure the trunkline and test jig wires go in the same direction. The other spring on the test jig will ground the probe body above the Wenner array. Make sure the springs are pulled out far enough to make a solid contact on the dipoles.



EC Load Test

	Target (mS/m)	Actual (mS/m)	Δ (%)	P/F	
Test 1	195.0				run
Test 2	97.0				run
Test 3	24.0				run

EC (mS/m) 0.00

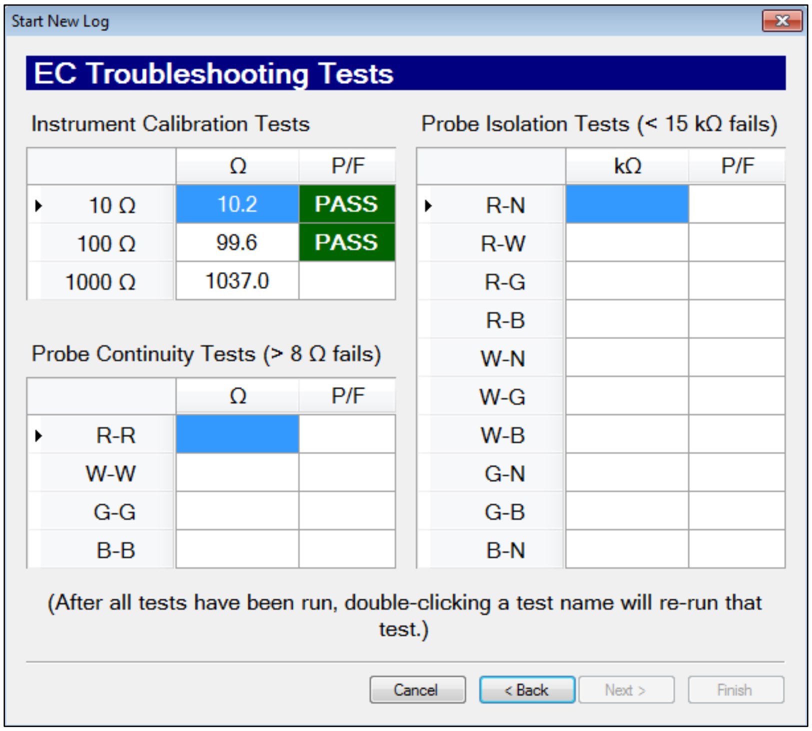
Hold down appropriate button on test load before selecting "capture".

Figure 5.4: EC Load Test Screen

5. When you get to the EC Load Test Screen and the EC test load and test jig are in place on the probe press down on the test 1 button on the test load and select “run” of Test 1 (Fig. 5.4). After 5 seconds the actual value will acquire and will pass if within 10% of the target value. Continue on with Test 2 and 3.

6. If any of the EC load tests fail do not pass within the allowed 10% acceptance range you can make adjustments on the test jig and rerun the test by just re-clicking the “run” button for an individual test.

7. If the tests continue to fail, select “Next” and the software will conduct the “EC Troubleshooting Tests.” The Instrument Calibration Tests (Fig. 5.5) checks of the calibration within the FI6000. If these are far out of range it will influence the EC Test load values and will need to return to Geoprobe® for repair. The “Probe Continuity and Isolation Tests” confirm each of the wires is a complete circuit and is fully isolated from one another. If a probe continuity test fails just outside the target range of <8ohms this is typically a contact issue with the test jig and the dipoles. If the continuity is in the thousands of ohms this is a break in the EC wire circuit – either in the probe, the trunkline or the connection between them.



EC Troubleshooting Tests

Instrument Calibration Tests

	Ω	P/F
10 Ω	10.2	PASS
100 Ω	99.6	PASS
1000 Ω	1037.0	

Probe Continuity Tests (> 8 Ω fails)

	Ω	P/F
R-R		
W-W		
G-G		
B-B		

Probe Isolation Tests (< 15 kΩ fails)

	kΩ	P/F
R-N		
R-W		
R-G		
R-B		
W-N		
W-G		
W-B		
G-N		
G-B		
B-N		

(After all tests have been run, double-clicking a test name will re-run that test.)

Figure 5.5: EC Troubleshooting Test Screen

8. When these tests are complete select next. In the next screen, the software will provide an EC option, if one is available. The EC Load Test will only work if EC can be operated in Wenner array meaning all of the EC wires in the continuity test pass with results <8ohms on the individual circuits. EC can be operated and collect good data in one of the dipole areas: top, middle or bottom dipole. If the R-R test fails but the others pass the software will provide the option in the next screen to run either middle dipole or bottom dipole arrays. If R-R and G-G are both an incomplete circuit then no EC array is available to run and a new probe must be connected or the problem fixed. In the Wenner configuration it requires 2 adjacent dipoles to operate in dipole mode. If an EC array is chosen and run in this last manner then all of the EC information collected will be bad data.

B. HPT Reference Testing

Reference testing is done to ensure that the HPT pressure sensor is in working order and to evaluate the condition of the HPT injection screen. The HPT reference test calculates atmospheric pressure which is required to obtain static water level readings and to determine the estimated K values for the log in our post log processing software the DI Viewer.

Reference Test Procedure

1. Connect a clean water source to the HPT controller and turn on the pump.

2. Allow water to flow through the system long enough so that no air remains in the trunkline or probe (air in the system can cause inaccurate flow and pressure measurements).

3. Insert the probe into the HPT reference tube and allow the water to flow out the valve adjusting the flow rate to between 250-300ml/min (Fig. 5.5). Ensure that the reference tube is close to vertical.

4. With a stable pressure reading and the water flowing out of the valve select "capture" - bottom with flow (Fig. 5.6)

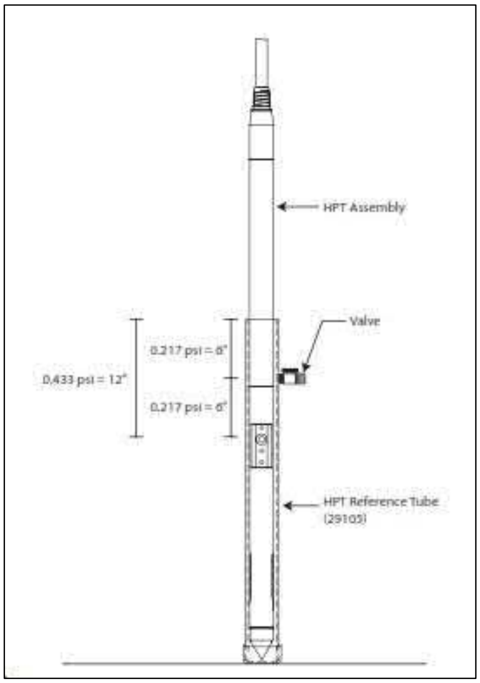
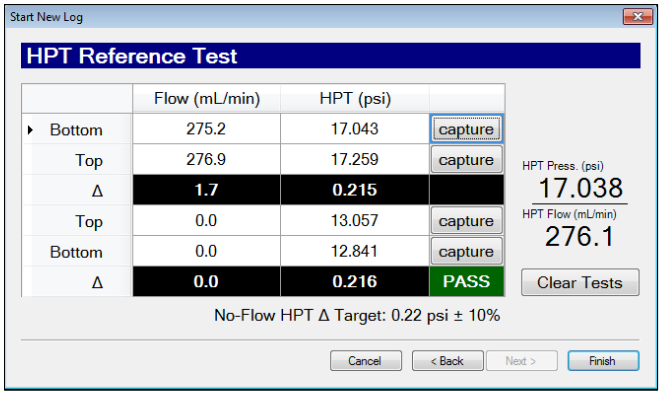


Figure 5.5: HPT Reference Test Setup

5. Close the valve and allow the water to overflow the top of the tube. When the pressure stabilizes select "capture" - top with flow.

6. Shut off the water flow. When the pressure stabilizes select "capture" - top flow = 0.

7. Open the valve and allow the water to drain out. When the pressure stabilizes select "capture" - bottom flow = 0.



	Flow (mL/min)	HPT (psi)	
Bottom	275.2	17.043	capture
Top	276.9	17.259	capture
Δ	1.7	0.215	
Top	0.0	13.057	capture
Bottom	0.0	12.841	capture
Δ	0.0	0.216	PASS

HPT Press. (psi) 17.038

HPT Flow (mL/min) 276.1

No-Flow HPT Δ Target: 0.22 psi ± 10%

Figure 5.6: HPT Reference Test Screen

The HPT reference test reading flow = 0 is the true test of the condition of the pressure sensor and is the only sensor test to have a pass/fail reading on it. Ideally, the pressure difference between the top and bottom values will be 0.22psi (1.52kPa). Typical pressure readings of the sensor will be in the 12-15psi (83-104kPa) range.

5.4 Running an HPT Log

1. Place the rod wiper on the ground over the probing location and install the drive cushion in place of the anvil of the probing machine.

2. Place the probe tip in the center of the rod wiper, and place the slotted drive cap on top of the HPT probe.

3. Start the HPT water flow. **Note**: It is important that there is always water flowing when the probe is advanced to avoid soil particles from moving through the screen and causing problems with the pressure readings or causing a blockage behind the screen.

4. Adjust the probe so that it is vertical and advance the probe until the HPT screen is at the ground surface.

5. Click the trigger button in the lower right hand corner of computer screen. (The Trigger label will flash and the background will change from yellow to green).

9. Advance the probe at a rate of 2cm/s. If necessary, feather the hammer to maintain this advance rate.

10. Perform a dissipation test (Section 5.4) in a zone of higher permeability indicated by lower HPT pressure.

11. After completing the log, press the trigger button again and select “Stop Log”.

12. Pull the rod string using either the rod grip pull system or a slotted pull cap. Run a post-log EC test and HPT response test (Section 5.2).

5.5 Performing a Dissipation Test

At least one dissipation test must be performed in order to calculate the static water level and estimated K readings from the log. Dissipation tests need to be performed below the water table and are best in zones of high permeability where the injection pressure can dissipate off quickly once the flow is shut off.

1. Stop in a zone of higher permeability which is indicated by lower HPT inject pressure.

2. Switch the DI Acquisition display view from the depth screen to the time screen by pressing the F10 key (F9 and F10 toggle between the depth and time screen of the acquisition software).

3. The screen will be grayed out which means that the data up to that point has not been saved. Select “Start Dissipation Test” which will turn the screen from gray to a white background indicating that you are now saving the time data.

4. Now shut the pump switch off and when the line pressure reaches zero, turn the flow valve off.

5. The HPT Pressure will begin to drop (dissipate the hydrostatic increase) and allow it to stabilize so very little visible drop in pressure is seen. When the pressure has fully dissipated turn the flow valve and the pump switch back on. When the flow and pressure are reestablished select “End Dissipation test.”

6. Select F9 to return to the depth screen and advancing the tool into the ground.

   Note: Performing a dissipation test in zones of higher permeability may only take 30 seconds or so but if the HPT pressure was higher to start with it may take a long time up to several hours to dissipate off to equilibrium. This is why targeting the most permeable zone to perform the dissipation tests is most desirable.

6.0 HPT Log and Interpretation

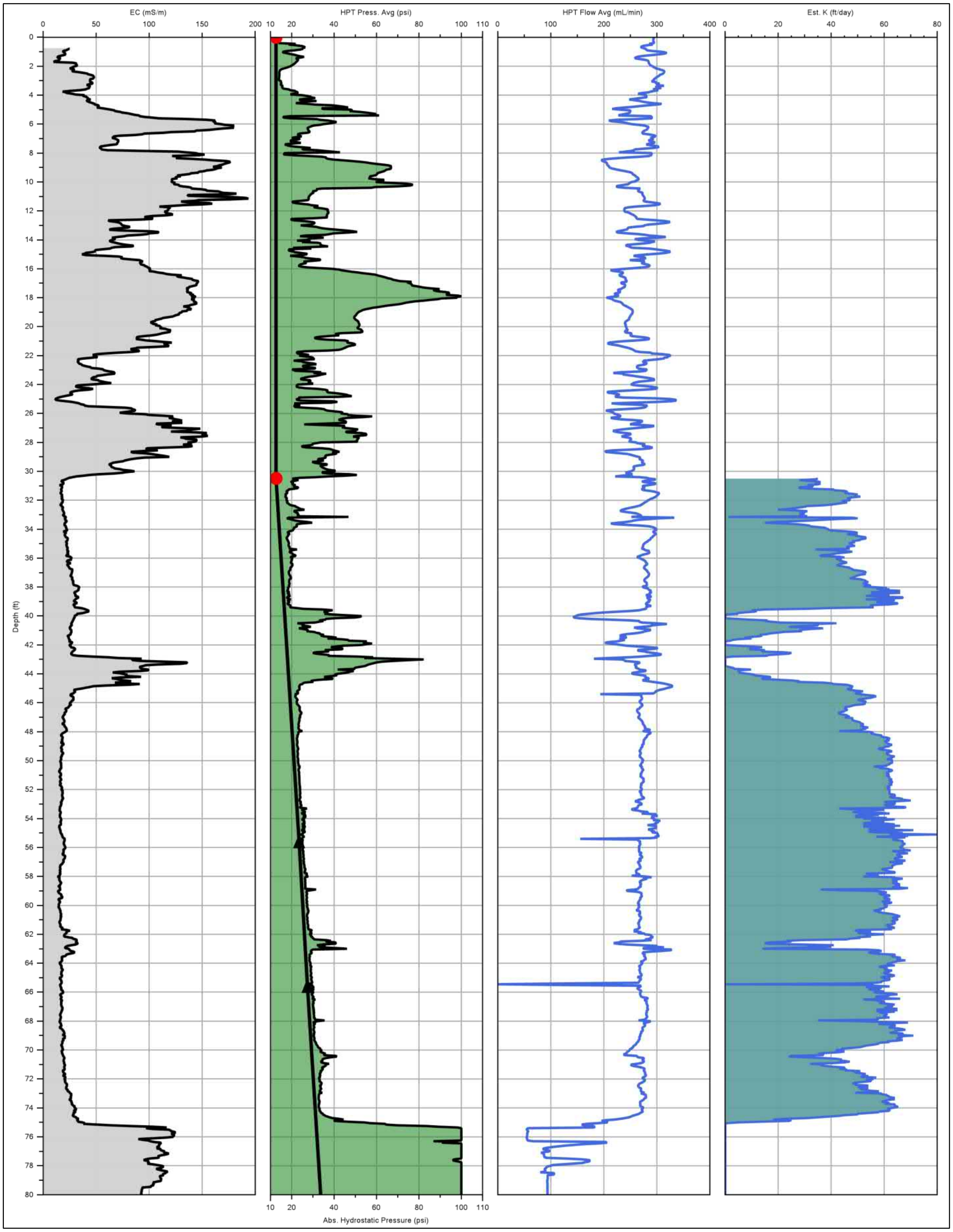


Figure 6.1: HPT Log file showing (left to right):
Electrical Conductivity (EC), HPT Injection Pressure with Hydrostatic Profile, HPT Flow, and Estimated K

A typical HPT log is shown in figure 6.1, which consists of both the HPT pressure response and electrical conductivity. In general, both HPT pressure and EC values increase with decreasing grain size, and decrease with increasing grain size. The log in Figure 6.1 shows good consistency between EC and HPT pressure for the majority of the log. It is only between 32'-42'bgs that we see some divergence of the graphs with higher HPT pressure while the EC readings remained low. This can happen for reasons such as poor mineralogy of the soil. Refusal was encountered in a shale layer beginning at 75'bgs and it can be noted that as we enter this layer the HPT flow gets suppressed as the pressure reaches a maximum value of 100psi (690kPa). The second graph of the log shows the hydrostatic profile on the secondary series of the graph. The hydrostatic profile has 2 black triangles which indicate where dissipation tests were run and used to calculate the profile. The red circle indicates the calculated water table based upon where the hydrostatic profile intersects atmospheric pressure. The fourth graph is the estimate K or groundwater flow graph. This is calculated based upon HPT pressure and HPT flow relationships. Less permeable soil will have less groundwater flow.

It is fairly common to see zones where EC readings and HPT pressure contradict one another. In cases where EC readings are low and HPT pressure trends higher as in the log in Figure 6.1 the following are possible reasons:

- Poor mineralogy of the soil particles resulting in silt and clay soils with very low EC readings. This is seen in many locations along the east coast of the United States.
- Silts intermixed with sand particles.
- Weathered bedrock may have low EC but would have low permeability.

Where we have cases of higher EC and lower HPT pressure typically is due to an ionic influence in the soil or groundwater. These higher EC readings can range from very slight to higher than typical soil readings. Very high EC readings can occur when the probe contacts metallic objects in the soil which will ground them out and typically will cause hard sharp spikes in the EC data.

- Chloride or other ionic contaminant (sea water, injection materials)
- Sea Water intrusion
- Wire, metal objects or Slag

In cases where HPT and EC do not confirm one another it is important to take confirmation soil and/or groundwater samples to help understand the difference between the two graphs.

7.0 Troubleshooting

7.1 Using the HPT Controller Test Load

The HPT Controller Test Load (206552) is included with the HPT Controller to help troubleshoot the HPT pressure sensor, trunkline, and controller. If there is a major problem with the HPT pressure sensor or the system wiring the system will not read anywhere close to atmospheric pressure with the probe at the surface. Commonly if the HPT sensor has broken the software will read either a maximum or minimum value which would be 100psi or 0psi (690kPa or 0kPa). If there is damaged wiring or nothing is connected to the controller the system typically reads 50psi (345kPa).

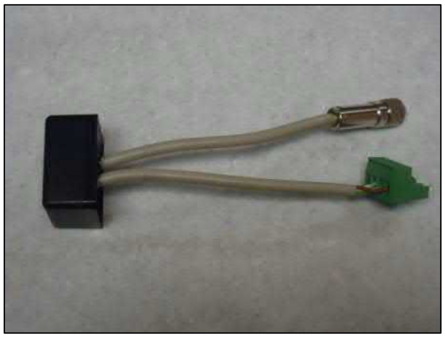


Figure 7.1: HPT Test Load (206552)

To use the test load, set up the system as previously described. Turn on both the field instrument and HPT controller and start the HPT software. Plug the green wire connector of the test load into the HPT sensor connector on the back of the HPT controller. If the pressure sensor value reads between 25-35psi (172 – 241kPa) the controller is able to properly read pressures so the problem is in the trunkline or the HPT sensor. If HPT controller has not moved from what it was reading or is way out from the expected value of the load test the HPT controller may require servicing. Contact Geoprobe Systems® for service.

Next, connect the HPT sensor wires of the trunkline to the controller with the green connector and then connect the chrome connector side of the test load to the female chrome connector on the downhole end of the trunkline in place of the pressure sensor. Again, the pressure value displayed on the field instrument should read between 25-35psi (172 – 241kPa) and should be the same as what was seen with the load test connected into the controller. If the load test read the expect value 25-35psi (172 – 241kPa) at both locations then both the trunkline and the controller are working properly and the problem is in the HPT sensor. If the test load read the expected value at the controller but not at the end of the trunkline, the trunkline may be defective and should be replaced. Before restringing another HPT trunkline, first connect the new trunkline sensor wires into the HPT controller and the downhole end into the test load. If the system now reads in the expected test load range the original trunkline needs replacing.

Finally, connect the pressure sensor to the trunkline. If it reads atmospheric pressure, approximately 12-15psi (83-104kPa), then the pressure transducer is functioning properly. However, if it does not, replace the sensor with a new one and re-check the pressure reading. Be sure to enter the new sensor calibration values into the software prior to starting the new log. Additional pressure sensors may be purchased from Geoprobe®.

7.2 Common Problems

Problem: The pressure transducer is connected to the trunkline, but the software is reporting a reading of ~ 50psi (345kPa).
Solution: Make sure all trunkline wires are secured to the green terminal blocks and plugged in to the back of the HPT controller and sensor chrome connectors are secure. Check components using the HPT Controller Test Load (Section 7.1).

Problem: The pressure transducer is connected to the trunkline, but the software is reporting a reading of 100psi or 0psi (690kPa or 0kPa).
Solution: Make sure all of the connections are good and recheck the pressure reading. If still bad connect a new HPT pressure sensor onto the trunkline and see if it reads atmospheric pressure. If not check all the components using the HPT Controller Test Load (Section 7.1).

Problem: The pressure with flow values keep drifting when water is flowing out the port or over the top of the reference tube.
Solution 1: If the trunkline was just connected and flow was just started air may still be in the lines. Allow the water to continue to flow through system which will purge out the remaining air. When it appears that most of the air is out of the lines press your thumb over the injection screen for a few seconds to help drive out any remaining air from the trunkline.
Solution 2: There may be debris behind the screen. Remove the HPT screen with the membrane wrench and turn the water flow on, use a small screwdriver to scrap out any debris in the screen socket as well as any that might be behind the screen. Replace the screen and retry the reference test with flow.
Solution 3: If the with flow pressure values continue to not settle down and provide close to the expected difference for a 6” water column then the problem may be inside the HPT control box. When you remove the cover of the HPT controller there will be a brass filter located on the left side when viewing from the front of the instrument (Fig 7.2). Particulates and precipitates can collect inside this filter causing problems with HPT pressure stability. Remove this filter and open up using appropriate wrenches. The filter can be easily cleaned by rinsing water over the screen. Reassemble and return to its proper location inside the control box. Resume reference testing the system.

Figure 7.2: Location of Inline Filter in K6300 and buildup of particulates in filter.

Problem: Atmospheric pressure values are way off from normal (12-15psi (83-104kPa)) after installing a new HPT sensor.
Solution: Check the calibration values that were entered into the software to ensure that they are correct.

Problem: Winterizing the HPT system for subfreezing work or air transport.
Solution: Pump RV antifreeze through the HPT pump and bypass pathway which can be done by blocking off the inject line. The trunkline can either be purge free of water by the pump or with an air compressor. NOTE: Never purge the HPT Controller of water using an air compressor this will damage sensor components in the controller.

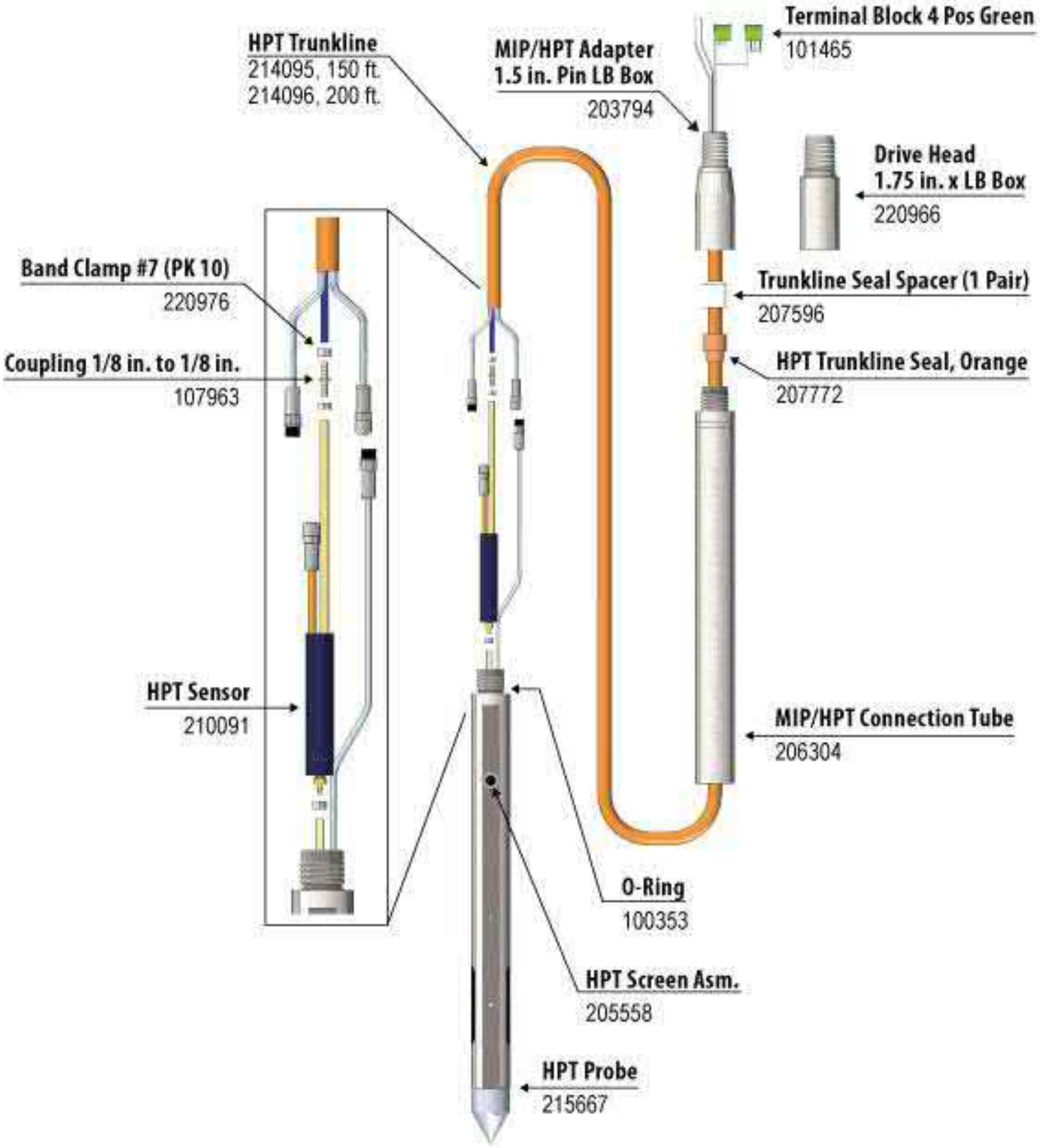
Problem: HPT flow sensor reading 0ml/min
Solution: If the flow sensor reads 0 or some other stabile number that does not correspond to actual water flow out the controller likely the flow sensor has been damaged. The flow sensor is very susceptible to damage from freezing. To repair the HPT flow sensor contact Geoprobe-DI technical support.

Problem: EC won't pass the QA tests.
Solution: Check the trunkline to probe EC connections ensuring they are tight. Run the troubleshooting tests (Section 5.3A), test EC on a new probe. If multiple probes and trunklines do not pass EC isolate the FI6000 instrument using the EC bypass cable (204025). The bypass cable is a six inch long cable that connects between the Test input and the EC probe connections on the back of the FI6000. Once connected start an EC or HPT log and fail the EC test load tests on purpose and run the EC troubleshooting tests (Figure 5.5). If the EC calibration or the EC continuity readings fail there could be an issue in the FI6000. In this case contact Geoprobe-DI technical support. If all of the troubleshooting tests pass then the problem is not in the instrument but in the trunkline, probe or their connections.

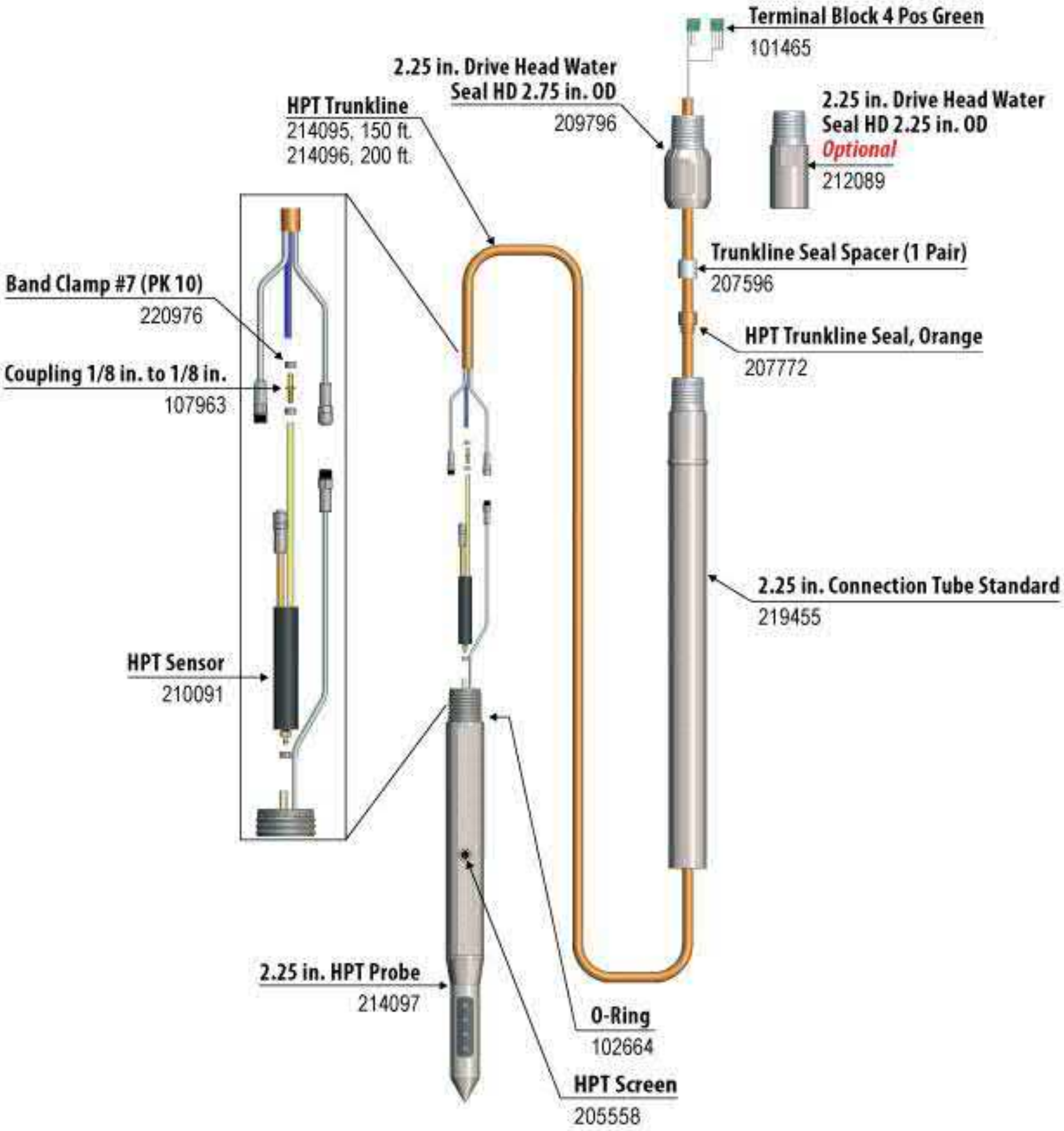
APPENDIX I

HPT Tool Configurations

HPT – K6050 (1.5 in / 1.75 in. system)



HPT – K8050 (2.25 in. system)



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Appendix C
Treatability Test Reagent Safety Data Sheets

Safety Data Sheet

according to 29CFR1910/1200 and GHS Rev. 3

Effective date : 12.14.2014

Sodium Hydroxide, 0.5M

SECTION 1 : Identification of the substance/mixture and of the supplier

Product name : **Sodium Hydroxide, 0.5M**

Manufacturer/Supplier Trade name:

Manufacturer/Supplier Article number: **S25881**

Recommended uses of the product and uses restrictions on use:

Manufacturer Details:

AquaPhoenix Scientific
9 Barnhart Drive, Hanover, PA 17331

Supplier Details:

Fisher Science Education
15 Jet View Drive, Rochester, NY 14624

Emergency telephone number:

Fisher Science Education Emergency Telephone No.: 800-535-5053

SECTION 2 : Hazards identification

Classification of the substance or mixture:

Corrosive
Serious eye damage, category 1
Corrosive to metals, category 1
Skin corrosion, category 1B

Skin Corr. 1B
Eye corr. 1
Metal Corr. 1

Signal word :Danger

Hazard statements:
May be corrosive to metals
Causes severe skin burns and eye damage
Causes serious eye damage

Precautionary statements:
If medical advice is needed, have product container or label at hand
Keep out of reach of children
Read label before use
Keep only in original container
Do not breathe dust/fume/gas/mist/vapours/spray
Wash … thoroughly after handling
Wear protective gloves/protective clothing/eye protection/face protection
Absorb spillage to prevent material damage
IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing
IF SWALLOWED: Rinse mouth. Do NOT induce vomiting
Wash contaminated clothing before reuse
IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing

Immediately call a POISON CENTER or doctor/physician
Store in a corrosive resistant/… container with a resistant inner liner
Store locked up
Dispose of contents/container to …

Other Non-GHS Classification:

WHMIS

NFPA/HMIS

NFPA SCALE (0-4)

Health	3
Flammability	0
Physical Hazard	0
Personal Protection	X

HMIS RATINGS (0-4)

SECTION 3 : Composition/information on ingredients

Ingredients:		
CAS 1310-73-2	Sodium Hydroxide	2 %
CAS 7732-18-5	Deionized Water	98 %
		Percentages are by weight

SECTION 4 : First aid measures

Description of first aid measures

After inhalation: Move exposed individual to fresh air. Loosen clothing as necessary and position individual in a comfortable position.Seek medical advice if discomfort or irritation persists.If breathing difficult, give oxygen.

After skin contact: Take off contaminated clothing and shoes immediately.Wash affected area with soap and water.Seek medical attention if irritation, discomfort persist.

After eye contact: Protect unexposed eye. Rinse/flush exposed eye(s) gently using water for 15-20 minutes. Remove contact lens(es) if able to do so during rinsing. Immediately get medical assistance.

After swallowing: Rinse mouth thoroughly. Do not induce vomiting. Have exposed individual drink sips of water. Seek medical attention if irritation, discomfort or vomiting persists.

Most important symptoms and effects, both acute and delayed:

Irritation, Nausea,Headache, Shortness of breath.;

Indication of any immediate medical attention and special treatment needed:

If seeking medical attention, provide SDS document to physician.

SECTION 5 : Firefighting measures

Extinguishing media

Suitable extinguishing agents: If in laboratory setting, follow laboratory fire suppression procedures. Use appropriate fire suppression agents for adjacent combustible materials or sources of ignition

For safety reasons unsuitable extinguishing agents:

Special hazards arising from the substance or mixture:

Combustion products may include carbon oxides or other toxic vapors.Thermal decomposition can lead to release of irritating gases and vapors.Sodium oxides.

Advice for firefighters:

Protective equipment: Use NIOSH-approved respiratory protection/breathing apparatus.

Additional information (precautions): Move product containers away from fire or keep cool with water spray as a protective measure, where feasible.

SECTION 6 : Accidental release measures

Personal precautions, protective equipment and emergency procedures:

Wear protective equipment. Transfer to a disposal or recovery container.Use respiratory protective device against the effects of fumes/dust/aerosol. Keep unprotected persons away. Ensure adequate ventilation.Keep away from ignition sources. Protect from heat.

Environmental precautions:

Prevent from reaching drains, sewer or waterway. Collect contaminated soil for characterization per Section 13

Methods and material for containment and cleaning up:

If in a laboratory setting, follow Chemical Hygiene Plan procedures.Place into properly labeled containers for recovery or disposal. If necessary, use trained response staff/contractor.Collect liquid and dilute with water. Neutralize with dilute acid solutions. Decant water to drain with excess water. Absorb with suitable material. Dispose of remaining solid as normal refuse. Always obey local regulations.

Reference to other sections:

SECTION 7 : Handling and storage

Precautions for safe handling:

Absorb spillage to prevent material damage due to corrosiveness to metal. Avoid contact with eyes, skin, and clothing. Wash hands after handling. Do not mix with acids.Follow good hygiene procedures when handling chemical materials. Use only in well ventilated areas.

Conditions for safe storage, including any incompatibilities:

Protect from freezing and physical damage.Provide ventilation for containers. Avoid storage near extreme heat, ignition sources or open flame. Store away from foodstuffs. Store away from oxidizing agents.Store in cool, dry conditions in well sealed containers. Store with Corrosives.

SECTION 8 : Exposure controls/personal protection

Control Parameters:	1310-73-2, Sodium Hydroxide, OSHA PEL TWA 2 mg/m3 1310-73-2, Sodium Hydroxide, ACGIH TLV TWA 2 mg/m3
Appropriate Engineering controls:	Emergency eye wash fountains and safety showers should be available in the immediate vicinity of use/handling.Provide exhaust ventilation or other engineering controls to keep the airborne concentrations of vapor or dusts (total/respirable) below the applicable workplace exposure limits (Occupational Exposure Limits-OELs) indicated above.
Respiratory protection:	Not required under normal conditions of use. Use suitable respiratory protective device when high concentrations are present. Use suitable respiratory protective device when aerosol or mist is formed. For spills, respiratory protection may be advisable.
Protection of skin:	The glove material has to be impermeable and resistant to the product/ the substance/ the preparation being used/handled.Selection of the glove material on consideration of the penetration times, rates of diffusion and the degradation.
Eye protection:	Safety glasses with side shields or goggles.
General hygienic measures:	The usual precautionary measures are to be adhered to when handling chemicals. Keep away from food, beverages and feed sources. Immediately remove all soiled and contaminated clothing. Wash hands before breaks and at the end of work. Do not inhale gases/fumes/dust/mist/vapor/aerosols. Avoid contact with the eyes and skin.

SECTION 9 : Physical and chemical properties

Appearance (physical state,color):	Clear, colorless liquid	**Explosion limit lower**: **Explosion limit upper**:	Non Explosive Non Explosive
Odor:	Odorless	**Vapor pressure**:	14mmHg @ 20C
Odor threshold:	Not Determined	**Vapor density**:	>1
pH-value:	Alkaline	**Relative density**:	Approx 1
Melting/Freezing point:	Approx 0°C	**Solubilities**:	Soluble in Water
Boiling point/Boiling range:	Approx 100°C	**Partition coefficient (n-octanol/water)**:	Not Determined
Flash point (closed cup):	Not Determined	**Auto/Self-ignition temperature**:	Not Determined
Evaporation rate:	Not Determined	**Decomposition temperature**:	Not Determined
Flammability (solid,gaseous):	Not Determined	**Viscosity**:	a. Kinematic:Not Determined b. Dynamic: Not Determined
Density: Not Determined			

SECTION 10 : Stability and reactivity

Reactivity:
Chemical stability: No decomposition if used and stored according to specifications.
Possible hazardous reactions:
Conditions to avoid: Incompatible materials, excess heat

Incompatible materials:acids, Organic materials, Chlorinated solvents, Aluminum, Phosphorus, Tin/tin oxides, Zinc
Hazardous decomposition products:sodium oxides, hydrogen. Carbon oxides (CO, CO2).

SECTION 11 : Toxicological information

Acute Toxicity: No additional information.	
Chronic Toxicity: No additional information.	
Corrosion Irritation: No additional information.	
Sensitization:	No additional information.
Single Target Organ (STOT):	No additional information.
Numerical Measures:	No additional information.
Carcinogenicity:	No additional information.
Mutagenicity:	No additional information.
Reproductive Toxicity:	No additional information.

SECTION 12 : Ecological information

Ecotoxicity Persistence and degradability: Readily degradable in the environment.
Bioaccumulative potential: Not Bioaccumulative.
Mobility in soil:
Other adverse effects:

SECTION 13 : Disposal considerations

Waste disposal recommendations:

Product/containers must not be disposed together with household garbage. Do not allow product to reach sewage system or open water.It is the responsibility of the waste generator to properly characterize all waste materials according to applicable regulatory entities (US 40CFR262.11). Consult federal state/ provincial and local regulations regarding the proper disposal of waste material that may incorporate some amount of this product.Neutralize with dilute acid solutions.

SECTION 14 : Transport information

UN-Number

1824

UN proper shipping name

Sodium hydroxide solution

Transport hazard class(es)

Class:
8 Corrosive substances

Packing group:II
Environmental hazard:
Transport in bulk:

Special precautions for user:

SECTION 15 : Regulatory information

United States (USA)

SARA Section 311/312 (Specific toxic chemical listings):

None of the ingredients is listed

SARA Section 313 (Specific toxic chemical listings):

None of the ingredients is listed

RCRA (hazardous waste code):

None of the ingredients is listed

TSCA (Toxic Substances Control Act):

All ingredients are listed.

CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act):

1310-73-2 Sodium Hydroxide 1000 lb

Proposition 65 (California):

Chemicals known to cause cancer:

None of the ingredients is listed

Chemicals known to cause reproductive toxicity for females:

None of the ingredients is listed

Chemicals known to cause reproductive toxicity for males:

None of the ingredients is listed

Chemicals known to cause developmental toxicity:

None of the ingredients is listed

Canada

Canadian Domestic Substances List (DSL):

All ingredients are listed.

Canadian NPRI Ingredient Disclosure list (limit 0.1%):

None of the ingredients is listed

Canadian NPRI Ingredient Disclosure list (limit 1%):

1310-73-2 Sodium Hydroxide

SECTION 16 : Other information

This product has been classified in accordance with hazard criteria of the Controlled Products Regulations and the SDS contains all the information required by the Controlled Products Regulations.Note:. The responsibility to provide a safe workplace remains with the user.The user should consider the health hazards and safety information contained herein as a guide and should take those precautions required in an individual operation to instruct employees and develop work practice procedures for a safe work environment.The information contained herein is, to the best of our knowledge and belief, accurate.However, since the conditions of handling and use are beyond our control, we make no guarantee of results, and assume no liability for damages incurred by the use of this material.It is the responsibility of the user to comply with all applicable laws and regulations applicable to this material.

GHS Full Text Phrases:

Abbreviations and acronyms:
IMDG: International Maritime Code for Dangerous Goods
PNEC: Predicted No-Effect Concentration (REACH)
CFR: Code of Federal Regulations (USA)
SARA: Superfund Amendments and Reauthorization Act (USA)
RCRA: Resource Conservation and Recovery Act (USA)
TSCA: Toxic Substances Control Act (USA)
NPRI: National Pollutant Release Inventory (Canada)
DOT: US Department of Transportation
IATA: International Air Transport Association
GHS: Globally Harmonized System of Classification and Labelling of Chemicals
ACGIH: American Conference of Governmental Industrial Hygienists
CAS: Chemical Abstracts Service (division of the American Chemical Society)
NFPA: National Fire Protection Association (USA)
HMIS: Hazardous Materials Identification System (USA)
WHMIS: Workplace Hazardous Materials Information System (Canada)
DNEL: Derived No-Effect Level (REACH)

Effective date : 12.14.2014
Last updated : 03.25.2015

REDOX SOLUTIONS, LLC

"...providing sulfide reagents for treatment of COPR and other metal-bearing wastes..."

Material Safety Data Sheet

FerroBlack (Hybrid)

Section 1: CHEMICAL PRODUCT and COMPANY IDENTIFICATION

1.1 Product Name:	FerroBlack
Chemical Family:	Inorganic salt solution
Synonyms:	IRON (II) SULFIDE, FERROUS SULPHIDE, IRON (II) SULPHIDE
Formula:	FeS
1.2 Manufacturer Information:	Redox Solutions, LLC 11550 N. Meridian Street, Suite 180 Carmel, IN 46032
1.3 Emergency Contact:	(317) 660-6867

Section 2: COMPOSITION, INFORMATION ON INGREDIENTS

2.1 Chemical Ingredients (% by wt.)

Ferrous Sulfide Slurry	CAS #:1317-37-9	7%-8%
Sodium Hydrosulfide	CAS #:16721-80-5	1%-2%
Water	CAS #:7732-18-5 71	80% -82%

Section 3: HAZARDS IDENTIFICATION

NFPA: **Health - 0** **Flammability - 0** **Reactivity - 2**

May be irritating to eyes and mucous membranes. Avoid inhalation of any fumes which may be given off when used or when bottle is opened. Consider toxic orally or by inhalation. LD/TD no data. PEL/TLV:TWA 1mg(Fe)/m^3. No known carcinogenicity.

Section 4: FIRST AID MEASURES

4.1 EYES: Immediately flush with large quantities of water for 15 minutes. Hold eyelids apart during irrigation to insure thorough flushing of the entire area of the eye and lids. Obtain immediate medical attention.

4.2 SKIN: Immediately flush with large quantities of water. Remove contaminated clothing under a safety shower.

4.3 INGESTION: If swallowed, give water or milk and induce vomiting. Call a physician.

Section 5: FIRE FIGHTING MEASURES

5.1 FLAMMABLE PROPERTIES

FLASH POINT: Not flammable **METHOD USED:** NA

5.2 EXTINGUISHING MEDIA: Use extinguishing media appropriate for surrounding fire

Section 6: ACCIDENTAL RELEASE MEASURES

6.1 Releases: Confine and absorb small releases on sand, earth or other inert absorbent. Dispose in accordance with all applicable environmental regulations.

Section 7: HANDLING and STORAGE

7.1 Handling: Use only with adequate ventilation. Use protective clothing to prevent contact with skin or eyes.

7.2 Storage: Store in well ventilated areas. Do not store combustibles in the area of storage vessels. Keep away from any sources of heat or flame. Store tote and smaller containers out of direct sunlight at moderate temperatures [<80º F (27º C)]. (See addendum for materials of construction)

Section 8: EXPOSURE CONTROLS, PERSONAL PROTECTION

8.1 RESPIRATORY PROTECTION:	None required if adequate ventilation is provided.
8.2 SKIN PROTECTION:	Proper Gloves
8.3 EYE PROTECTION:	Safety glasses with side-shield.

Section 9: PHYSICAL and CHEMICAL PROPERTIES

9.1 APPEARANCE:	Black liquid with visible suspended solids
9.2 ODOR:	No appreciable odor.
9.3 BOILING POINT:	Not determined
9.4 VAPOR PRESSURE:	Not determined (Believed to be minimal)
9.5 VAPOR DENSITY:	Not determined
9.6 SOLUBILITY IN WATER:	Insoluble.
9.7 SPECIFIC GRAVITY:	1.21
9.8 FREEZING POINT:	Not determined
9.9 pH:	9.5 – 12.3

9.10 VOLATILE: Not applicable

Section 10: STABILITY and REACTIVITY

10.1 STABILITY: This is a stable material

10.2 HAZARDOUS POLYMERIZATION: Will not occur.

10.3 INCOMPATIBILITY: Acids will cause the release of highly toxic Hydrogen Sulfide. Reacts violently with diazonium salts. Sodium Hydrosulfide solution is not compatible with copper, zinc, aluminum or their **alloys** (i.e. bronze, brass, galvanized metals, etc.). Corrosive to steel above 150º F (65.5º C). These materials of construction should not be used in handling systems or storage containers for this product.

Section 11: TOXICOLOGICAL INFORMATION

Not generally regarded as a health hazard.

Section 12: DISPOSAL CONSIDERATIONS

If released to the environment for other than its intended purpose, this product should be checked to see it meets the criteria of a reactive sulfide D003, Reactive waste.

Section 14: TRANSPORT INFORMATION

14.1 DOT Shipping Name: Non-hazardous, Non-Regulated Liquid (Ferrous Sulfide Slurry)

14.2 DOT Hazard Class: NA

14.3 UN/NA Number: NA

14.4 Packing Group: NA

14.5 DOT Placard: NA

14.6 DOT Label(s): NA

14.7 IMO Shipping Name: Not Determined

14.8 RQ (Reportable Quantity): NA

14.9 RR STCC Number: Not Determined

Section 13: DISCLOSURE

While the information and recommendations contained herein are based on data that is believed to be correct, Redox Solutions, LLC makes no guarantee or warranty of any kind, expressed or implied with respect to the information contained herein. We reserve the right to revise material safety data sheets periodically as new information becomes available. (MSDS Revised: 6/27/10)

EnviroBlend®
Metal Waste Treatment by Premier Magnesia, LLC

SAFETY DATA SHEET

Issue Date 02-Dec-2014 **Revision Date** 19-Aug-2014 **Version** 1

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING

Product identifier

Product Name	ENVIROMAG fi Coarse

Other means of identification

Product Code	ENVIROMAG fi Coarse
Synonyms	Light Burned Magnesium Oxide, Caustic Calcined Magnesia, MgO, Magnesium Oxide,

Recommended use of the chemical and restrictions on use

Recommended Use	Heavy metals remediation product.
Uses advised against	No information available

Details of the supplier of the safety data sheet

Manufacturer Address
Premier Magnesia, LLC, 300 Barr Harbor Drive, Suite 250, West Conshohocken, PA 19428

Emergency telephone number

Company Phone Number	610-828-6929
24 Hour Emergency Phone Number	Chemtrec 1-800-424-9300
Emergency Telephone	Chemtrec 1-800-424-9300

2. HAZARDS IDENTIFICATION

Classification

OSHA Regulatory Status
Product dust is classified as a "nuisance particulate, not otherwise regulated" as specified by ACGHI and OSHA. The excessive, long-term inhalation of mineral dusts may contribute to the development of industrial bronchitis, reduced breathing capacity, and may lead to the increased susceptibility to lung disease. This chemical is not considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.122)

Not a dangerous substance or mixture according to the Globally Harmonized System (GHS)

Label elements

Emergency Overview

The product contains no substances which at their given concentration, are considered to be hazardous to health

Appearance Granular **Physical state** Solid **Odor** Odorless

Causes mild irritation to the eyes
Low toxicity by skin contact.
Chronic overexposure by inhalation of airborne particulate may irritate upper respiratory system as well as the throat.
Ingestion is an unlikely route of exposure. If ingested in large amounts it may cause irritation, nausea, vomiting, diarrhea, abdominal pain, black stool, pink urine, coma and possibly death.

Hazards not otherwise classified (HNOC)

Other Information

Unknown Acute Toxicity	100% of the mixture consists of ingredient(s) of unknown toxicity

3. COMPOSITION/INFORMATION ON INGREDIENTS

Common name	Magnesium Oxide # 1309-48-4.
Synonyms	Light Burned Magnesium Oxide, Caustic Calcined Magnesia, MgO, Magnesium Oxide,

Chemical Name	CAS No.	Weight-%	Trade Secret
Magnesium Oxide	1309-48-4	100	

4. FIRST AID MEASURES

First aid measures

Eye contact	Rinse thoroughly with plenty of water, also under the eyelids. (Get medical attention immediately if irritation persists.).
Skin Contact	Wash skin with soap and water.
Inhalation	Remove to fresh air. If breathing has stopped, give artificial respiration. Get medical attention immediately.
Ingestion	Not an expected route of exposure. Drink 1 or 2 glasses of water. Never give anything by mouth to an unconscious person. Do not induce vomiting without medical advice. Immediate medical attention is required.

Most important symptoms and effects, both acute and delayed

Symptoms No information available.

Indication of any immediate medical attention and special treatment needed

Note to physicians Treat symptomatically.

5. FIRE-FIGHTING MEASURES

Suitable extinguishing media
Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

Unsuitable extinguishing media Water reacts with magnesium oxide producing magnesium hydroxide and heat. Do not allow water to get inside containers: reaction with water will cause product to swell, generate heat, and burst its container. If contact is unavoidable, use sufficient water to safely absorb the heat that may be generated.

Specific hazards arising from the chemical
No information available.

Explosion data

Sensitivity to Mechanical Impact	None.
Sensitivity to Static Discharge	None.

Protective equipment and precautions for firefighters
As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures

Personal precautions Ensure adequate ventilation, especially in confined areas.

Environmental precautions

Environmental precautions	See Section 12 for additional ecological information.

Methods and material for containment and cleaning up

Methods for containment	Prevent further leakage or spillage if safe to do so.
Methods for cleaning up	Carefully clean up and place material into a suitable container, being careful to avoid creating excessive dust. If conditions warrant, clean up personnel should wear approved respiratory protection, gloves and goggles to prevent irritation from contact and/or inhalation.

7. HANDLING AND STORAGE

Precautions for safe handling

Advice on safe handling	Use personal protective equipment as required.

Conditions for safe storage, including any incompatibilities

Storage Conditions	Keep container tightly closed in a dry and well-ventilated place. Avoid generation of dust. Do not allow contact with water.
Incompatible materials	Interhalogens, bromine pentafluoride, chlorine trifluoride. Contact with aluminum metal may release hydrogen gas. Incandescent reaction wtih phosphorus pentachloride. Water will react with magnesium oxide to form magnesium hydroxide and release heat and steam.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Control parameters

Exposure Guidelines	This product, as supplied, does not contain any hazardous materials with occupational exposure limits established by the region specific regulatory bodies.

Chemical Name	ACGIH TLV	OSHA PEL	NIOSH IDLH
Magnesium Oxide 1309-48-4	TWA: 10 mg/m^3 inhalable fraction	TWA: 15 mg/m^3 fume, total particulate (vacated) TWA: 10 mg/m^3 fume and total particulate	IDLH: 750 mg/m^3 fume

NIOSH IDLH Provide workers with NIOSH approved respirators in accordance with requirements of 29 CFR 1910. 134 for level of exposure incurred.

Appropriate engineering controls

Engineering Controls	Provide sufficient ventilation, in both volume and air flow patterns to control mist/dust concentrations below allowable exposure limits. Showers. Eyewash stations.

Individual protection measures, such as personal protective equipment

Eye/face protection	Avoid contact with eyes. The use of eye protection is recommended.
Skin and body protection	The use of eye protection, gloves and long sleeve clothing is recommended.
Respiratory protection	Provide workers with NIOSH approved respirators in accordance with requirements of 29 CFR 1910. 134 for level of exposure incurred.
General Hygiene Considerations	Wash hands thoroughly after handling.

9. PHYSICAL AND CHEMICAL PROPERTIES

Information on basic physical and chemical properties

Physical state	Solid

Appearance	Granular	**Odor**	Odorless
Color	Brownish	**Odor threshold**	No information available

Property	**Values**	**Remarks • Method**
pH	10-11	
Melting point/freezing point	>2100 °C >3800 °F	
Boiling point / boiling range	No information available	
Flash point	No information available	
Evaporation rate	Not Applicable	
Flammability (solid, gas)	No information available	
Flammability Limit in Air		
Upper flammability limit:	No information available	
Lower flammability limit:	No information available	
Vapor pressure	No information available	
Vapor density	No information available	
Specific Gravity	3.56	
Water solubility	Slight <1%	
Solubility in other solvents	No information available	
Partition coefficient	No information available	
Autoignition temperature	No information available	
Decomposition temperature	No information available	
Kinematic viscosity	No information available	
Dynamic viscosity	No information available	
Explosive properties	No information available	
Oxidizing properties	No information available	

Other Information

Softening point	No information available
Molecular weight	No information available
VOC Content (%)	No information available
Density	No information available
Bulk density	70-90 lb/ft3

10. STABILITY AND REACTIVITY

Reactivity
No data available

Chemical stability
Stable under recommended storage conditions.

Possibility of Hazardous Reactions
None under normal processing.

Hazardous polymerization Hazardous polymerization does not occur.

Conditions to avoid
Extremes of temperature and direct sunlight.

Incompatible materials
Interhalogens, bromine pentafluoride, chlorine trifluoride. Contact with aluminum metal may release hydrogen gas. Incandescent reaction wtih phosphorus pentachloride. Water will react with magnesium oxide to form magnesium hydroxide and release heat and steam.

Hazardous Decomposition Products
Heat and steam.

11. TOXICOLOGICAL INFORMATION

Information on likely routes of exposure

Product Information	Magnesium Oxide # 1309-48-4
Inhalation	Inhalation of fume (not MgO dust particulate) produced upon decomposition of magnesium compounds can produce a febrile reaction and leukocytosis in humans.
Eye contact	No data available.
Skin Contact	No data available.
Ingestion	No data available.

Information on toxicological effects

Symptoms No information available.

Delayed and immediate effects as well as chronic effects from short and long-term exposure

Sensitization	No information available.
Germ cell mutagenicity	No information available.
Carcinogenicity	No information available.
Reproductive toxicity	No information available.
STOT - single exposure	No information available.
STOT - repeated exposure	No information available.
Aspiration hazard	No information available.

Numerical measures of toxicity - Product Information

Unknown Acute Toxicity 100% of the mixture consists of ingredient(s) of unknown toxicity

12. ECOLOGICAL INFORMATION

Ecotoxicity

No data available on any adverse effects of this material on the environment

100% of the mixture consists of components(s) of unknown hazards to the aquatic environment

Persistence and degradability
No information available.

Bioaccumulation
No information available.

Other adverse effects No information available

13. DISPOSAL CONSIDERATIONS

Waste treatment methods

Disposal of wastes	This produce does not exhibit any characteristics of a hazardous waste. The product is suitable for landfill disposal once the free water component is evaporated or absorbed by a suitable absorbent (earth). Follow all applicable federal, state and local regulations for safe disposal.
Contaminated packaging	Do not reuse container.

14. TRANSPORT INFORMATION

DOT	Not regulated Not regulated by DOT as a hazardous material. No hazard class, label or placard required, no UN or NA number assigned.

15. REGULATORY INFORMATION

International Inventories

TSCA Complies

Chemical Name	TSCA	DSL/NDSL	EINECS/ELINCS	ENCS	IECSC	KECL	PICCS	AICS
Magnesium Oxide	X	X	X	X	X	X	X	X

X - Listed

TSCA - United States Toxic Substances Control Act Section 8(b) Inventory
DSL/NDSL - Canadian Domestic Substances List/Non-Domestic Substances List
EINECS/ELINCS - European Inventory of Existing Chemical Substances/European List of Notified Chemical Substances
ENCS - Japan Existing and New Chemical Substances
IECSC - China Inventory of Existing Chemical Substances
KECL - Korean Existing and Evaluated Chemical Substances
PICCS - Philippines Inventory of Chemicals and Chemical Substances
AICS - Australian Inventory of Chemical Substances

US Federal Regulations

SARA 313

This product does not contain any substances reportable under Sections 302, 304 or 313. Sections 311 and 312 do apply. (Routine Reporting and Chemical Inventories)

SARA 311/312 Hazard Categories

Acute health hazard	No
Chronic Health Hazard	No
Fire hazard	No
Sudden release of pressure hazard	No
Reactive Hazard	No

CWA (Clean Water Act)

This product does not contain any substances regulated as pollutants pursuant to the Clean Water Act (40 CFR 122.21 and 40 CFR 122.42)

CERCLA

This material, as supplied, does not contain any substances regulated as hazardous substances under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302) or the Superfund Amendments and Reauthorization Act (SARA) (40 CFR 355). There may be specific reporting requirements at the local, regional, or state level pertaining to releases of this material

US State Regulations

California Proposition 65

This product does not contain chemicals known to the State of California to cause cancer, birthdefects or other reproductive toxins.

U.S. State Right-to-Know Regulations

Chemical Name	New Jersey	Massachusetts	Pennsylvania

Magnesium Oxide 1309-48-4	X	X	X

U.S. EPA Label Information

EPA Pesticide Registration Number Not Applicable

16. OTHER INFORMATION

NFPA	**Health hazards** 1	**Flammability** 0	**Instability** 0	**Physical and Chemical Properties** -
HMIS	**Health hazards** 0	**Flammability** 0	**Physical hazards** 0	**Personal protection** X

Issue Date	02-Dec-2014
Revision Date	19-Aug-2014

Revision Note

No information available

Disclaimer

The information provided in this Material Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

End of Safety Data Sheet

Technology-Based Solutions for the Environment

SAFETY DATA SHEET

1. Identification

Product identifier	**Metals Remediation Compound (MRC®)**
Other means of identification	None.
Recommended use	Soil and Groundwater Remediation.
Recommended restrictions	None known.

Manufacturer/Importer/Supplier/Distributor information

Company Name	Regenesis
Address	1011 Calle Sombra San Clemente, CA 92673
Telephone	949-366-8000
E-mail	CustomerService@regenesis.com
Emergency phone number	CHEMTREC® at 1-800-424-9300 (International)

2. Hazard(s) identification

Physical hazards	Not classified.	
Health hazards	Skin corrosion/irritation	Category 2
	Serious eye damage/eye irritation	Category 1
OSHA defined hazards	Not classified.	

Label elements

Signal word	Danger
Hazard statement	Causes skin irritation. Causes serious eye damage.

Precautionary statement

Prevention	Wash thoroughly after handling. Wear protective gloves. Wear eye/face protection.
Response	If on skin: Wash with plenty of water. If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a poison center/doctor. If skin irritation occurs: Get medical advice/attention. Take off contaminated clothing and wash before reuse.
Storage	Store away from incompatible materials.
Disposal	Dispose of waste and residues in accordance with local authority requirements.
Hazard(s) not otherwise classified (HNOC)	None known.

3. Composition/information on ingredients

Mixtures

Chemical name	CAS number	%
Glycerol Tripolylactate	201167-72-8	56-61
Glycerin	56-81-5	36-41
Lactic acid	50-21-5	<10
Sorbitol Cysteinate	444618-64-8	5

Composition comments	All concentrations are in percent by weight unless otherwise indicated.

4. First-aid measures

Inhalation	Move to fresh air. Call a physician if symptoms develop or persist.
Skin contact	Remove contaminated clothing. Wash with plenty of soap and water. If skin irritation occurs: Get medical advice/attention. Wash contaminated clothing before reuse.
Eye contact	Immediately flush eyes with plenty of water for at least 15 minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Get medical attention immediately.
Ingestion	Rinse mouth. Never give anything by mouth to a victim who is unconscious or is having convulsions. Do not induce vomiting without advice from poison control center. Get medical attention if symptoms occur.
Most important symptoms/effects, acute and delayed	Severe eye irritation. Symptoms may include stinging, tearing, redness, swelling, and blurred vision. Permanent eye damage including blindness could result. Skin irritation. May cause redness and pain.
Indication of immediate medical attention and special treatment needed	Provide general supportive measures and treat symptomatically. Keep victim under observation. Symptoms may be delayed.
General information	Ensure that medical personnel are aware of the material(s) involved, and take precautions to protect themselves.

5. Fire-fighting measures

Suitable extinguishing media	Water spray. Carbon dioxide (CO_2). Dry chemical powder. Foam.
Unsuitable extinguishing media	Do not use water jet as an extinguisher, as this will spread the fire.
Specific hazards arising from the chemical	During fire, gases hazardous to health may be formed. Combustion products may include: carbon oxides, phosphorus compounds and metal oxides.
Special protective equipment and precautions for firefighters	Self-contained breathing apparatus and full protective clothing must be worn in case of fire.
Fire fighting equipment/instructions	Move containers from fire area if you can do so without risk. Water spray should be used to cool containers.
Specific methods	Use standard firefighting procedures and consider the hazards of other involved materials.
General fire hazards	No unusual fire or explosion hazards noted.

6. Accidental release measures

Personal precautions, protective equipment and emergency procedures	Keep unnecessary personnel away. Keep people away from and upwind of spill/leak. Wear appropriate protective equipment and clothing during clean-up. Do not touch damaged containers or spilled material unless wearing appropriate protective clothing. Ensure adequate ventilation. Local authorities should be advised if significant spillages cannot be contained. For personal protection, see section 8 of the SDS.
Methods and materials for containment and cleaning up	Large Spills: Stop the flow of material, if this is without risk. Use water spray to reduce vapors or divert vapor cloud drift. Dike the spilled material, where this is possible. Cover with plastic sheet to prevent spreading. Absorb in vermiculite, dry sand or earth and place into containers. Following product recovery, flush area with water. Small Spills: Wipe up with absorbent material (e.g. cloth, fleece). Clean surface thoroughly to remove residual contamination. Never return spills to original containers for re-use. For waste disposal, see section 13 of the SDS.
Environmental precautions	Avoid discharge into drains, water courses or onto the ground.

7. Handling and storage

Precautions for safe handling	Do not get this material in contact with eyes. Avoid contact with eyes, skin, and clothing. Provide adequate ventilation. Wear appropriate personal protective equipment. Observe good industrial hygiene practices.
Conditions for safe storage, including any incompatibilities	Store in original tightly closed container. Store in a cool, dry, well-ventilated place. Store away from incompatible materials (see Section 10 of the SDS). Recommended storage containers: plastic lined steel, plastic, glass, aluminum, stainless steel, or reinforced fiberglass.

8. Exposure controls/personal protection

Occupational exposure limits

US. OSHA Table Z-1 Limits for Air Contaminants (29 CFR 1910.1000)

Components	Type	Value	Form
Glycerin (CAS 56-81-5)	PEL	5 mg/m3	Respirable fraction.
		15 mg/m3	Total dust.

Biological limit values	No biological exposure limits noted for the ingredient(s).
Appropriate engineering controls	Good general ventilation (typically 10 air changes per hour) should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level. Eye wash facilities and emergency shower must be available when handling this product.

Individual protection measures, such as personal protective equipment

Eye/face protection	Wear approved, tight fitting indirect vented or non-vented safety goggles where splashing is probable. Face shield is recommended.
Skin protection	
Hand protection	Wear appropriate chemical resistant gloves. Rubber or vinyl-coated gloves are recommended.
Other	Wear appropriate chemical resistant clothing.
Respiratory protection	If engineering controls do not maintain airborne concentrations below recommended exposure limits (where applicable) or to an acceptable level (in countries where exposure limits have not been established), an approved respirator must be worn.
Thermal hazards	Wear appropriate thermal protective clothing, when necessary.
General hygiene considerations	Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants.

9. Physical and chemical properties

Appearance	
Physical state	Liquid.
Form	Viscous gel/liquid.
Color	Amber.
Odor	Strong Amine/Sulfur.
Odor threshold	Not available.
pH	3 (3% solution/water)
Melting point/freezing point	Not available.
Initial boiling point and boiling range	Not available.
Flash point	Not available.
Evaporation rate	Not available.
Flammability (solid, gas)	Not applicable.
Upper/lower flammability or explosive limits	
Flammability limit - lower (%)	Not available.
Flammability limit - upper (%)	Not available.
Explosive limit - lower (%)	Not available.
Explosive limit - upper (%)	Not available.
Vapor pressure	Not available.
Vapor density	Not available.
Relative density	1.2 - 1.4
Solubility(ies)	
Solubility (water)	Not available.
Solubility (other)	Acetone and DMSO.

Partition coefficient (n-octanol/water)	Not available.
Auto-ignition temperature	Not available.
Decomposition temperature	Not available.
Viscosity	20,000 - 40,000 cP

10. Stability and reactivity

Reactivity	The product is stable and non-reactive under normal conditions of use, storage and transport.
Chemical stability	Undergoes hydrolysis in water to form lactic acid and glycerol.
Possibility of hazardous reactions	No dangerous reaction known under conditions of normal use.
Conditions to avoid	Avoid temperatures exceeding the flash point. Contact with incompatible materials.
Incompatible materials	Strong oxidizing agents. Bases. Acids.
Hazardous decomposition products	Thermal decomposition or combustion may produce: carbon oxides, phosphorus compounds, metal oxides.

11. Toxicological information

Information on likely routes of exposure

Inhalation	May cause irritation to the respiratory system.
Skin contact	Causes skin irritation.
Eye contact	Causes serious eye damage.
Ingestion	Ingestion may cause irritation and malaise.
Symptoms related to the physical, chemical and toxicological characteristics	Severe eye irritation. Symptoms may include stinging, tearing, redness, swelling, and blurred vision. Permanent eye damage including blindness could result. Skin irritation. May cause redness and pain.

Information on toxicological effects

Acute toxicity

Components	Species	Test Results
Glycerin (CAS 56-81-5)		
Acute		
Oral		
LD50	Rat	12600 mg/kg

Skin corrosion/irritation	Causes skin irritation.
Serious eye damage/eye irritation	Causes serious eye damage.

Respiratory or skin sensitization

Respiratory sensitization	Not a respiratory sensitizer.
Skin sensitization	This product is not expected to cause skin sensitization.
Germ cell mutagenicity	No data available to indicate product or any components present at greater than 0.1% are mutagenic or genotoxic.
Carcinogenicity	This product is not considered to be a carcinogen by IARC, ACGIH, NTP, or OSHA.

OSHA Specifically Regulated Substances (29 CFR 1910.1001-1050)

Not listed.

Reproductive toxicity	This product is not expected to cause reproductive or developmental effects.
Specific target organ toxicity - single exposure	Not classified.
Specific target organ toxicity - repeated exposure	Not classified.
Aspiration hazard	Not an aspiration hazard.

12. Ecological information

Ecotoxicity	The product is not classified as environmentally hazardous. However, this does not exclude the possibility that large or frequent spills can have a harmful or damaging effect on the environment.
Persistence and degradability	Material is readily degradable and undergoes hydrolysis in several hours.

Bioaccumulative potential	No data available.

Partition coefficient n-octanol / water (log Kow)

Glycerin (CAS 56-81-5)	-1.76
Lactic acid (CAS 50-21-5)	-0.72

Mobility in soil	No data available.
Other adverse effects	None known.

13. Disposal considerations

Disposal instructions	Collect and reclaim or dispose in sealed containers at licensed waste disposal site. Dispose of contents/container in accordance with local/regional/national/international regulations.
Local disposal regulations	Dispose in accordance with all applicable regulations.
Hazardous waste code	The waste code should be assigned in discussion between the user, the producer and the waste disposal company.
Waste from residues / unused products	Dispose of in accordance with local regulations. Empty containers or liners may retain some product residues. This material and its container must be disposed of in a safe manner (see: Disposal instructions).
Contaminated packaging	Empty containers should be taken to an approved waste handling site for recycling or disposal. Since emptied containers may retain product residue, follow label warnings even after container is emptied.

14. Transport information

DOT

Not regulated as dangerous goods.

IATA

Not regulated as dangerous goods.

IMDG

Not regulated as dangerous goods.

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code	Not established.

15. Regulatory information

US federal regulations	This product is a "Hazardous Chemical" as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200. One or more components are not listed on TSCA.

TSCA Section 12(b) Export Notification (40 CFR 707, Subpt. D)

Not regulated.

OSHA Specifically Regulated Substances (29 CFR 1910.1001-1050)

Not listed.

CERCLA Hazardous Substance List (40 CFR 302.4)

Not listed.

Superfund Amendments and Reauthorization Act of 1986 (SARA)

Hazard categories	Immediate Hazard - Yes Delayed Hazard - No Fire Hazard - No Pressure Hazard - No Reactivity Hazard - No

SARA 302 Extremely hazardous substance

Not listed.

SARA 311/312 Hazardous chemical	Yes

SARA 313 (TRI reporting)

Not regulated.

Other federal regulations

Clean Air Act (CAA) Section 112 Hazardous Air Pollutants (HAPs) List

Not regulated.

Clean Air Act (CAA) Section 112(r) Accidental Release Prevention (40 CFR 68.130)

Not regulated.

Safe Drinking Water Act (SDWA) Not regulated.

US state regulations

US. Massachusetts RTK - Substance List

Glycerin (CAS 56-81-5)

US. New Jersey Worker and Community Right-to-Know Act

Glycerin (CAS 56-81-5)

US. Pennsylvania Worker and Community Right-to-Know Law

Glycerin (CAS 56-81-5)

US. Rhode Island RTK

Not regulated.

US. California Proposition 65

California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65): This material is not known to contain any chemicals currently listed as carcinogens or reproductive toxins.

International Inventories

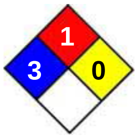
Country(s) or region	Inventory name	On inventory (yes/no)*
Australia	Australian Inventory of Chemical Substances (AICS)	Yes
Canada	Domestic Substances List (DSL)	Yes
Canada	Non-Domestic Substances List (NDSL)	No
China	Inventory of Existing Chemical Substances in China (IECSC)	Yes
Europe	European Inventory of Existing Commercial Chemical Substances (EINECS)	Yes
Europe	European List of Notified Chemical Substances (ELINCS)	No
Japan	Inventory of Existing and New Chemical Substances (ENCS)	Yes
Korea	Existing Chemicals List (ECL)	Yes
New Zealand	New Zealand Inventory	Yes
Philippines	Philippine Inventory of Chemicals and Chemical Substances (PICCS)	Yes
United States & Puerto Rico	Toxic Substances Control Act (TSCA) Inventory	Yes

*A "Yes" indicates this product complies with the inventory requirements administered by the governing country(s).
A "No" indicates that one or more components of the product are not listed or exempt from listing on the inventory administered by the governing country(s).

16. Other information, including date of preparation or last revision

Issue date	23-April-2015
Revision date	-
Version #	01
Further information	HMIS® is a registered trade and service mark of the American Coatings Association (ACA).
HMIS® ratings	Health: 3 Flammability: 1 Physical hazard: 0

NFPA ratings



Disclaimer Regenesis cannot anticipate all conditions under which this information and its product, or the products of other manufacturers in combination with its product, may be used. It is the user’s responsibility to ensure safe conditions for handling, storage and disposal of the product, and to assume liability for loss, injury, damage or expense due to improper use. The information in the sheet was written based on the best knowledge and experience currently available.

Safety Data Sheet

Solms Crushed Limestone (Crushed Rock, Limestone, Base Rock, Scrubber Stone, Agg-Lime)

Section 1: Identification

MANUFACTURER'S NAME & ADDRESS: Capitol Aggregates Inc.
2330 North Loop 1604 West.
San Antonio, Texas 78248

PRODUCT NAME:	**Solms Crushed Limestone**

EMERGENCY TELEPHONE NUMBER:	(210) 871-6111
SDS INFORMATION OR ASSISTANCE:	(210) 871-7247
COMPANY PHONE NUMBER:	(210) 871 7260
CHEMICAL NAME:	Solms Crushed Limestone
CAS NUMBER:	N/A
TRADE NAME or SYNONYMS:	(Crushed Rock, Limestone, Base Rock, Scrubber Stone, Agg-Lime)
PRODUCT USE:	Construction Aggregates, Soil Amendment

Section 2: Hazards Identification

WARNING! CRUSHED LIMESTONE IS NOT A KNOWN HEALTH HAZARD. HOWEVER CRUSHED LIMESTONE MAY BE SUBJECTED TO VARIOUS NATURAL OR MECHANICAL FORCES THAT PRODUCE SMALL PARTICLES (DUST), WHICH MAY CONTAIN RESPIRABLE CRYSTALLINE SILICA (PARTICLES LESS THAN 10 MICROMETERS IN AERODYNAMIC DIAMETER).REPEATED INHALATION OF RESPIRABLE CRYSTALLINE SILICA (QUARTZ) MAY CAUSE DAMAGE TO LUNGS THROUGH PROLONGED OR REPEATED EXPOSURE AND MAY CAUSE LUNG CANCER.

Classification of the substance or mixture:

CARCINOGENICITY/INHALATION — Category 1A

SPECIFIC TARGET ORGAN TOXICITY
(REPEATED EXPOSURE) — Category 2

GHS label elements

Hazard pictograms:

Signal word: **Danger**

Hazard statements: **Harmful if swallowed. May cause cancer (inhalation). May cause damage to lungs with prolonged or repeated exposure (inhalation).**

EMERGENCY OVERVIEW:

Appearance/Odor: Loose granular rock, gravel, and silt mixture of varying size and color. No odor.

Carcinogen, Acute & Chronic Toxin Warning:

- This product contains greater than 0.1% crystalline silica. Crystalline silica has been linked to cancer, silicosis, and other lung problems in conditions of prolonged airborne over-exposure. Repeated inhalation of respirable crystalline silica (quartz) may cause lung cancer according to IARC and NTP; ACGIH states that it is a suspected cause of cancer. Other forms of RCS (e.g. Tridymite and Cristobalite) may also be present or formed under certain industrial processes.
- Carcinogen- Acute & Chronic. Product contains crystalline silica quartz. The International Agency for Research on Cancer (IARC) classifies respirable crystalline silica as Group I – Known Human Carcinogen. The National Toxicology Program (NTP) lists respirable crystalline silica as a Known Human Carcinogen. The American Conference of Governmental Industrial Hygienists (ACGIH) lists respirable crystalline silica as a Suspected Human Carcinogen (A-2).

OSHA REGULATORY STATUS:

This product is considered HAZARDOUS by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

POTENTIAL HEALTH EFFECTS:

LIKELY ROUTES OF EXPOSURE: Inhalation

TARGET ORGAN(S): Lungs

EYE

- Avoid eye contact. Exposure to dust may be irritating to the eyes and may impair visibility. These effects are transient similar to nuisance dust and recovery should follow.

SKIN

- Avoid prolonged and repeated skin contact. Do not handle until all safety precautions have been read and understood. Wear protective gloves, protective clothing, eye protection and face protection. Wash hands thoroughly after handling.

INHALATION

- Avoid prolonged and repeated inhalation of dust. Acute and chronic exposure to dusts may be irritating to the respiratory tract by frictional action, and may provoke bronchoconstriction in hyper-susceptible individuals.
- Respirable dusts can cause bothersome deposits in the nasal passages. Nuisance dusts cause toxicity from physical overloading of the respiratory clearance mechanisms.
- Significant deterioration of pulmonary function and chronic bronchitis can develop with prolonged overexposure to dusts in excess of established limits (See Section 8).
- Continued overexposure to silica dust can result in silicosis, a chronic, progressive and sometimes fatal lung disease that is characterized by the presence of typical nodulation of the lungs leading to fibrosis. Silicosis can develop in weeks with high exposures and after years of lower exposure. Symptoms and signs of silicosis include cough, shortness of breath, wheezing, decreased pulmonary function, and changes in chest X-rays.

INGESTION

- Minute amounts accidentally ingested during industrial handling are not likely to cause injury.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE

- Chronic exposure to nuisance dusts may enhance susceptibility to respiratory tract infections.
- Silica can cause silicosis which, in turn, increases the risk of pulmonary tuberculosis infection.
- Smoking may increase the risk of developing lung disorders associated with silicosis.

Section 3: Composition / Information on Ingredients

Component	CAS No.	Wt.%	Hazardous?	GHS-US
Calcium Carbonate	1317-65-3	> 85	No	Not Classified
Crystalline Silica Quartz (a component of crushed stone)	14808-60-7	< 6	Yes	Acute Tox. 4 (Oral), H302 Carc. 1A, H350 STOT RE 1, H372

Crystalline Silica is reported as total silica and not just the respirable fraction.

Any concentration shown as a range is to protect confidentiality of trade secret information or is due to process variation.

Section 4: First Aid Measures

Description of necessary first aid measures

EYE CONTACT
Limestone dust: Immediately flush eyes with large amounts of water and continue flushing for 15 minutes. Remove contact lenses, if worn. Occasionally lift the eyelid(s) to ensure thorough rinsing. Beyond rinsing, do not attempt to remove material from the eye(s). Get medical attention if irritation develops or persists.

SKIN CONTACT
Limestone dust: Wash contaminated area thoroughly with soap and water. If redness or irritation occurs and persists, seek medical attention.

INHALATION
Limestone dust: Remove to fresh air. If breathing is difficult keep at rest in a position comfortable for breathing and get medical attention.

INGESTION
Limestone dust: If swallowed, do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Give large quantity of water and get medical attention if distress develops.

MOST IMPORTANT SYMPTOMS/EFFECTS, ACUTE and DELAYED POTENTIAL ACUTE HEALTH EFFECTS

Eye contact:	May cause eye irritation due to abrasion if crushed limestone particles become entrapped in the eyes. Symptoms may include discomfort or pain, excess blinking and tear production, with marked redness and swelling of the conjunctiva.
Inhalation:	May cause respiratory tract irritation. Symptoms may include sneezing or coughing similar to inhalation of nuisance dust particles if sand or gravel particles are inhaled. Inhaling sand and gravel may cause discomfort in the chest, shortness of breath and coughing.
Skin contact:	Symptoms may include skin abrasion or redness if sand and gravel particles collide forcefully with the skin.
Ingestion:	Harmful if swallowed. May cause stomach distress, nausea, choking, and vomiting if sand or gravel is swallowed.

OVER-EXPOSURE SIGNS/SYMPTOMS

Eye contact:	Adverse symptoms may include the following: pain, watering and redness
Inhalation:	Adverse symptoms may include the following: respiratory tract irritation and coughing. Prolonged inhalation may cause chronic health effects. This product contains crystalline silica. Prolonged or repeated inhalation of respirable crystalline liberated from silica can cause silicosis and may cause cancer.
Skin contact:	Adverse symptoms may include skin abrasion and redness.

Ingestion: Adverse symptoms may include stomach distress, nausea, vomiting, or choking if crushed stone is swallowed.

NOTES TO PHYSICIAN

Ensure that medical personnel are aware of the materials involved, and take precautions to protect themselves. Pre-existing medical conditions that may be aggravated by exposure include disorders of the eye, skin and lung (including asthma and other breathing disorders).If addicted to tobacco, smoking will impair the ability of the lungs to clear themselves of dust.

Section 5: Fire Fighting Measures

FLAMMABLE PROPERTIES:

Noncombustible and not explosive.

EXTINGUISHING MEDIA:

Suitable extinguishing media:	Crushed Limestone is not flammable. Use fire extinguishing media appropriate for surrounding materials.
Unsuitable extinguishing media:	None known.

SPECIFIC HAZARDS ARISING FROM THE CHEMICAL

No specific fire or explosion hazard. Not a combustible dust.

THERMAL DECOMPOSITION PRODUCTS

None specific however contact with powerful oxidizing agents and acids may cause fire and/or explosions (See section 10 of this safety data sheet).

PROTECTION OF FIREFIGHTERS:

No special precautions use protective equipment appropriate for surrounding materials.

Section 6: Accidental Release Measures

PERSONAL PRECAUTIONS:

Use personal protective equipment (PPE) specified in Section 8 (Exposure Controls/Personal Protection). Also see Section 3 (Hazards Identification), Section 7 (Handling & Storage), and Section 10 (Stability & Reactivity).

ENVIRONMENTAL PRECAUTIONS:

Do not allow spilled material to enter sewers or waterways.

METHODS OF CONTAINMENT:

Wet suppression can be used to minimize dust levels

METHODS FOR CLEAN-UP:

Clean up quickly and avoid generating dust. Spilled material where dust is generated, may overexpose cleanup personnel to respirable crystalline silica-containing dust. Do not dry sweep or use compressed air for clean-up. Wetting of spilled material and/or use of respiratory protection equipment may be necessary.

OTHER INFORMATION:
Notify appropriate local authorities of spills into sewers or waterways. See section 8 for further information on protective clothing and equipment, section 13 for advice on waste disposal.

Section 7: Handling and Storage

HANDLING:
Do not handle until all safety precautions have been read and understood. Keep formation of airborne dusts to a minimum. Provide appropriate exhaust ventilation at places where dust is formed. Do not breathe dust. Avoid prolonged and repeated exposure to dusts. Wet suppression can be used to minimize dust exposure. Provide adequate ventilation. Wear appropriate personal protective equipment. Observe good industrial hygiene practices. Avoid contact with eyes. Do not swallow. Avoid generating and breathing dust. Good housekeeping is important to prevent accumulation of dust. The use of compressed air for cleaning clothing, equipment, etc, is not recommended. DO NOT use product for sand blasting. Blasting breaks down natural silica and creates freshly fractured respirable crystalline silica which may lead to silica-related disease in persons exposed at levels exceeding occupational exposure limits.

ADVICE FOR GENERAL OCCUPATIONAL HYGIENE
Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Remove contaminated clothing and protective equipment before entering eating areas. See also Section 8 for additional information on hygiene measures.

STORAGE:
No special storage procedures are necessary. Avoid dust formation or accumulation. Keep workers off large piles of product to minimize dust levels or engulfment hazards. Do not enter a silo or other enclosure containing bulk quantities of these products without using all appropriate safety precautions as engulfment or suffocation may occur. Crushed Stone may form a surface crust which appears solid but may not support the weight of humans. Accordingly, do not stand on crushed stone without using all appropriate safety precautions, including, without limitation, properly employed harnesses, lifelines and all other necessary safety equipment.

OTHER:

Also see Section 8 (Exposure Controls/Personal Protection)

Section 8: Exposure Controls / Personal Protection

EXPOSURE GUIDELINES:

Component	CAS No.	Exposure Limits					
		OSHA		MSHA		ACGIH	
		respirable dust	total dust	respirable dust	total dust	respirable dust	total dust
Crushed Limestone (as Particulates Not Otherwise Regulated or Nuisance Dusts)	SEQ250	PEL 8hr-TWA: 5 mg/m^3	PEL 8hr-TWA: 15 mg/m^3	PEL 8hr-TWA: 5 mg/m^3	PEL 8hr-TWA: 10 mg/m^3	TLV 8hr-TWA: 3 mg/m^3	TLV 8hr-TWA: 10 mg/m^3
Crystalline Silica Quartz	14808-60-7	PEL 8hr-TWA: 10 mg/m^3 $/(\%SiO_2+2)$	PEL 8hr-TWA: 30 mg/m^3 $/(\%SiO_2+2)$	PEL 8hr-TWA: 10 mg/m^3 $/(\%SiO_2+2)$	PEL 8hr-TWA: 30 mg/m^3 $/(\%SiO_2+3)$	TLV 8hr-TWA: 0.025 mg/m^3	N/A

APPROPRIATE ENGINEERING CONTROLS:
Good general ventilation (typically 10 air changes per hour indoors) should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level.

PERSONAL PROTECTIVE EQUIPMENT (PPE):

EYE/FACE PROTECTION
Wear safety glasses or goggles.

SKIN PROTECTION
Wear standard work gloves (leather, cotton, coated cotton, etc.) as needed to prevent abrasion. Wear clothes with sleeve rolled down and collars buttoned, and trousers gathered at the ankles to minimize skin contact.

RESPIRATORY PROTECTION
When handling or performing work with crushed limestone that produces dust or respirable crystalline silica, a NIOSH approved respirator is recommended in poorly ventilated areas or when permissible exposure limits may be exceeded. Wear a NIOSH approved respirator that is properly fitted and is in good condition. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator. All respirators must be NIOSH-certified.

GENERAL HYGIENE CONSIDERATIONS
Practice good housekeeping and hygiene practices to minimize generating and spreading airborne dust. Always wash areas of the body (hands, face, arms, etc.) that have come in contact with the product. Always wash hands and face with soap and water before eating, drinking, or smoking.

Section 9: Physical and Chemical Properties

Physical State: Solid. [Granular, Pebbles to Boulders]

Color: White/Grayish White/ or Tan

Odor: Odorless.

Odor threshold: No data available.

pH: As Calcium Carbonate 8-9.

Melting point: No data available.

Boiling point: No data available

Flash point: Non-combustible.

Burning time: Not available.

Burning rate: Not available.

Evaporation rate: Not applicable.

Flammability (solid, gas): Not applicable

Lower and upper explosive (flammable) limits: Not applicable.

Vapor pressure: Not applicable.

Vapor density: Not applicable.

Relative density: > 2.0

Solubility: Insoluble in water.

Solubility in water: Not applicable

Partition coefficient: n-octanol/water: Not applicable.

Auto-ignition temperature: Not applicable.

Decomposition temperature: Not applicable.

SADT: Not available.

Viscosity: Not applicable.

Section 10: Stability and Reactivity

REACTIVITY
Product is stable and non-reactive under normal conditions of use but reacts vigorously with acids to form CO2. Ignites on contact with Fluorine.

CHEMICAL STABILITY:
Material is stable under normal conditions but reacts vigorously with acids to form CO2. Ignites on contact with Fluorine.

POSSIBILITY OF HAZARDOUS REACTIONS:
Avoid contact with strong oxidizers such as acids which will react vigorously and form CO2.

CONDITIONS TO AVOID:
Avoid generation of dusts. Avoid contact with strong oxidizers such as acids which will react vigorously and form CO2. Crushed Limestone should not be mixed or stored with Fluorine, Ammonium Salts, Aluminum, Hydrogen, Magnesium, or Acids.

INCOMPATIBLE MATERIALS:
Contact with powerful oxidizing agents such as Fluorine, Chlorine Tri-Fluoride, Manganese Trioxide, Oxygen Di-Fluoride, Ammonium Salts, Aluminum, Hydrogen, Magnesium, or Acids.

HAZARDOUS DECOMPOSITION PRODUCTS:
Silica-containing respirable dust particles may be generated if dust is generated. Limestone decomposes at 1742 degrees Farenheit to produce calcium oxide.

OTHER INFORMATION
See also additional precautions Section 5 (Fire Fighting Measures), Section 6 (Accidental Release Measures) and Section 7 (Handling & Storage).

Section 11: Toxicological Information

INFORMATION ON TOXICOLOGICAL EFFECTS

Acute toxicity: Not classified. Limestone LD50/LC50 of >6000mg/Kg (Rat, oral). Limestone is not listed by MSHA, OSHA, or IARC as a carcinogen but this product may contain trace amounts of crystalline silica, which has been classified by IARC as a carcinogenic to humans when inhaled in the form of quartz or Crystobalite.

Harmful if swallowed. May cause stomach distress, nausea, or vomiting

Irritation/Corrosion:

Skin: Not applicable.
Eyes: Not applicable.
Respiratory: May cause respiratory tract irritation.
Sensitization: Not applicable.

Carcinogenicity – May Cause Cancer
A; General Product Information:
The Occupational Safety and Health Administration (OSHA), the National Toxicology Program (NTP) and the International Agency for Research on Cancer (IARC) have not listed crushed limestone as a carcinogen.

B: Component Carcinogenicity Nuisance Dust-Crystalline Silica Dust

This product, however, may contain a constituent which is listed by IARC and NTP as carcinogen. Respirable crystalline silica in the form of quartz or cristobalite from occupational sources is listed by the International Agency for Research on Cancer (IARC) and National

Toxicology Program (NTP) as a lung carcinogen. Prolonged exposure to respirable crystalline silica has been known to cause silicosis, a lung disease, which may be disabling. While there may be a factor of individual susceptibility to a given exposure to respirable silica dust, the risk of contracting silicosis and the severity of the disease is clearly related to the amount of dust exposure and the length of time (usually years) of exposure.

Chronic Toxicity

Specific target organ toxicity – (repeated/extended exposure), Crystalline Silica is considered hazardous by inhalation. IARC has classified silica as a Group 1 substance, carcinogenic to humans. This classification is based on the findings of laboratory animal studies (inhalation and implantation) and epidemiology studies that were considered sufficient for carcinogenicity. NTP has also classified respirable crystalline silica as a known carcinogen. Excessive exposure to crystalline silica can cause silicosis, a chronic, progressive and sometimes fatal lung disease which, in turn, increases the risk of pulmonary tuberculosis infection.

Mutagenicity: There are no data available.

Reproductive Toxicity : Not applicable

Specific target organ toxicity (single exposure): Not Applicable

Specific target organ toxicity (repeated exposure)

Name	Category	Route of Exposure	Target Organs
Quartz	1	Inhalation	Respiratory tract and kidneys

Aspiration Hazard: There are no data available

INFORMATION ON LIKELY ROUTES OF EXPOSURE

Symptoms related to the physical, chemical and toxicological characteristics:

Eye contact: Limestone dust: May cause irritation through mechanical abrasion. Discomfort in the chest, shortness of breath, coughing. Adverse symptoms associated with eye contact with particle debris include the following: discomfort, excess blinking, tear production, watering, marked redness and swelling of the conjunctiva.

Inhalation: Limestone dust: May cause respiratory tract irritation. Adverse symptoms may include respiratory tract irritation and coughing. Prolonged inhalation may cause chronic health effects. This product contains crystalline silica. Prolonged or repeated inhalation of respirable crystalline silica liberated from this product can cause silicosis, a fibrosis (scarring) of the lungs, and may cause cancer.

Skin contact: Limestone dust: Adverse symptoms may include skin abrasion and redness.

Ingestion: Limestone dust: Harmful if swallowed. Adverse symptoms may include stomach distress, nausea, or vomiting.

Section 12: Ecological Information

ECOTOXICITY
Not expected to be harmful to aquatic organisms. Discharging crushed stone, sand, dust and fines into waters may increase total suspended particulate (TSP) levels that can be harmful to certain aquatic organisms.

PERSISTENCE and DEGRADABILITY
Not Applicable

BIOACCUMULATIVE POTENTIAL
Not Applicable

MOBILITY IN SOIL
Not Applicable

OTHER ADVERSE EFFECTS
No other adverse environmental effects (e.g. ozone depletion, photochemical ozone creation potential, global warming potential) are expected from this component.

Section 13: Disposal Considerations

Recover or recycle if possible.

REGULATORY INFORMATION
Disposal must comply with all applicable federal, state and local regulations.

WASTE DISPOSAL METHODS
The generation of waste should be avoided or minimized wherever possible. Disposal of this product should comply with the applicable requirements of environmental protection and waste disposal legislation and any regional local authority applicable requirements. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor. Do not allow fine particulate matter to drain into sewers/water supplies. Do not contaminate ponds, waterways or ditches with fine particulates. Waste packaging should be recycled. Incineration or landfill should only be considered when recycling is not feasible. This material and its container must be disposed of in a safe manner. Care should be taken when handling empty containers that have not been cleaned or rinsed out. Empty containers or liners may retain some product residues. Avoid dispersal of spilled material and runoff, and contact with soil, waterways, drains and sewers. Dispose of waste materials only in accordance with applicable federal, state, and local laws and regulations.

HAZARDOUS WASTE CODE
Not Regulated. Crushed Limestone is used in many soil and construction applications, waste material does not meet the criteria of a hazardous waste as defined under the Resource Conservation And Recovery Act (RCRA), 40 CFR 261. Dispose of residual products and empty containers responsibly and lawfully.

Section 14: Transport Information

UN NUMBER
Not Applicable

UN PROPER SHIPPING NAME
Not Applicable

BASIC SHIPPING DESCRIPTION:
U.S. Department of Transportation (DOT) Highway/Rail (Bulk): Not classified
U.S. Department of Transportation (DOT) Highway/Rail (Non-bulk): Not classified

ADDITIONAL INFORMATION:

The DOT description is provided to assist in the proper shipping classification of this product and may not be suitable for all required shipping descriptions. Many local communities and jurisdictions regulate the transporting of Crushed Stone in open vehicles or trailers requiring tarps, covering, or other protections of the load.

Section 15: Regulatory Information

OSHA:
This product is considered Hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200) and should be included in employers' hazardous communication programs.

TSCA:
Crushed Limestone is not listed on TSCA (Toxic Substances Control Act) inventory, however a component Quartz (CAS 14808-60-7) is listed on the United States Toxic Substances Control Act inventory.

CERCLA:
This product in not listed as a CERCLA hazardous substance

CLEAN AIR ACT

Clean Air Act Section 112 (b): Hazardous Air Pollutants (HAPs) — Not listed
Clean Air Act Section 602: Class I Substances — Not listed
Clean Air Act Section 602: Class II Substances — Not listed

DEA

DEA List I Chemicals: (Precursor Chemicals) — Not listed
DEA List II Chemicals: (Essential Chemicals) — Not listed

SAFE DRINKING WATER ACT
Not Listed

SARA TITLE III:

Hazard categories:	Immediate Hazard – No Delayed Hazard – Yes Fire Hazard – No Pressure Hazard – No Reactivity Hazard - No

Section 302:
This product is not and does not contain an Extremely Hazardous Substance
Section 311/312:
The following materials are reportable under the Tier II rules:
Crystalline Silica Quartz

Section 313:
The following TRI chemicals are present in this product:

Chemical Name	CAS No.	Wt%
None		

INTERNATIONAL REGULATIONS
Not applicable since not shipped internationally.

US STATE REGULATIONS:

California Proposition 65:
This product contains the following chemicals known to the State of California to cause cancer:

Name	CAS Number
Crystalline Silica	14808-60-7

California law requires the manufacturer to give the above warning in the absence of definitive testing to prove that the defined risks do not exist.

Massachusetts Right To Know Substance List
Crystalline Silica (Quartz) (CAS 14808-60-7)
Respirable Tridymite and Cristobalite (other forms of crystalline silica) (CAS Mixture)

New Jersey Worker and Community Right-to-Know Act
Crystalline Silica (Quartz) (CAS 14808-60-7)
Respirable Tridymite and Cristobalite (other forms of crystalline silica) (CAS Mixture)

Pennsylvania Worker and Community Right-to-Know Law
Crystalline Silica (Quartz) (CAS 14808-60-7)
Respirable Tridymite and Cristobalite (other forms of crystalline silica) (CAS Mixture

Rhode Island Right To Know Substance List
Not regulated.

Section 16: Other Information

NFPA Ratings:

Health: 1
Flammability: 0
Reactivity: 0
0 = minimal hazard, 1 = slight hazard, 2 = moderate hazard, 3 = severe hazard, 4 = extreme hazard

Capitol Aggregates Inc.
2330 North Loop 1604 West.
San Antonio, Texas 78248
(210)-871-6111

PRECAUTIONARY WARNING!
CRUSHED LIMESTONE, (SOLMS CRUSHED LIMESTONE), IS NOT A KNOWN HEALTH HAZARD. ALTHOUGH CRUSHED LIMESTONE MAY BE SUBJECTED TO VARIOUS NATURAL OR MECHANICAL FORCES THAT PRODUCE SMALL PARTICLES (DUST), WHICH MAY CONTAIN RESPIRABLE CRYSTALLINE SILICA (PARTICLES LESS THAN 10 MICROMETERS IN AERODYNAMIC DIAMETER).REPEATED INHALATION OF RESPIRABLE CRYSTALLINE SILICA (QUARTZ) MAY CAUSE DAMAGE TO LUNGS THROUGH PROLONGED OR REPEATED EXPOSURE AND MAY CAUSE SILICOSIS A FORM OF LUNG CANCER. DO NOT USE PRODUCT FOR SAND BLASTING. BLASTING BREAKS DOWN NATURAL SILICA AND CREATES FRESHLY FRACTURED RESPIRABLE CRYSTALLINE SILICA WHICH MAY LEAD TO SILICA-RELATED DISEASE IN PERSONS EXPOSED AT LEVELS EXCEEDING OCCUPATIONAL EXPOSURE LIMITS. BEFORE USING, ALSO READ THE SAFETY DATA SHEET FOR THIS PRODUCT FOUND AT WWW.CAPITOLAGGREGATES.COM.

KEEP OUT OF THE REACH OF CHILDREN (Poison Control No. 1-800-222-1222)

Product Identifier:
SOLMS CRUSHED LIMESTONE
CAS NO. N/A

Hazard Statement **DANGER**
Harmful if swallowed. May cause damage to lungs with prolonged or repeated exposure (inhalation). May cause cancer, (inhalation).

ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
CAS	Chemical Abstract Service
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DOT	Department of Transportation
IARC	International Agency for Research on Cancer
m^3	Cubic meter
mg	Milligram
SDS	Safety Data Sheet (formerly known as MSDS)
MSHA	Mine Safety and Health Administration
N/A	Not applicable
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NTP	National Toxicology Program
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PPE	Personal Protective Equipment
RQ	Reportable Quantity
TLV	Threshold Limit Value
TRI	Toxic Release Inventory
TSCA	Toxic Substance Control Act

NOTE: This SDS attempts to describe as accurately as possible the potential exposures associated with normal use of this product. Health and safety precautions on this data sheet may not be adequate for all individuals and/or situations. Users have the responsibility to evaluate and use this product safely and to comply with all applicable environmental, health, and safety laws and regulations.

Prepared in August 2015
Supersedes any and all previous versions (extensive revisions were made)

Disclaimer of Warranty:

While the information provided herein is believed to provide a useful summary of the hazards of different types of Crushed Limestone designated above as commonly used, this SDS cannot anticipate and provide all of the information that might be needed by every individual in every situation. Inexperienced users should obtain proper training prior to using any Crushed Limestone product and no one should use any Crushed Limestone product without following all applicable safety laws and regulations related to its storage, handling, use and disposal and without first understanding the potential hazards of Crushed Limestone. This SDS does not cover such potential hazards.

The information provided in this SDS is believed by Capitol Aggregates, Inc. to be accurate at the time it was prepared or it was prepared from sources then believed to be reliable. It is the responsibility of the user independently to investigate and understand other pertinent sources of information and to comply with all laws, regulations and procedures applicable to the safe storage, handling, use and disposal of Crushed Limestone. It is also the responsibility of the user to independently determine the suitability or fitness of any of the products covered by this SDS for their intended uses.

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Dear Customer

Whether you are a long term customer or a new contractor, we would like to thank you for purchasing Capitol Aggregates Products. We are a Texas owned Company and produce all of our products in the State of Texas. This Safety Data Sheet (SDS), provided for the product you purchased or intend to use is a revision and replaces any previous versions formerly known as Material Safety Data Sheets or (MSDS). We are providing you this SDS as required by the Mine Safety & Health Administration's (MSHA), or the Occupational Safety & Health Administration, OSHA, and any applicable State Right-To –Know laws. The requirements applicable to the OSHA and MSHA Hazard Communication Standards can be found at 29 CFR 1910.1200 for OSHA and 30 CFR 47 for MSHA.

It is an important responsibility for you as a customer or contractor to communicate this information to your employees, customers, and contractors who may use, contact, or be exposed to this product. It is also an important consideration and responsibility for you to follow any applicable laws that require you to forward a copy of this SDS to your customers or end users. Please direct this SDS to the person responsible for safety and health compliance at your company as they may be able to assist you with any of the necessary requirements. If you need additional copies or have questions about this SDS please contact 210-871-6111, or visit us at www.capitolaggregates.com .

Spanish language versions will be available in the near future at www.capitolaggregates.com .

Sincerely

Chuck Ross
Director of Safety

LabChem
performance through chemistry

Calcium Carbonate

Safety Data Sheet

according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

Date of issue: 04/10/2014 Revision date: 12/29/2016 Supersedes: 07/08/2016 Version: 1.2

SECTION 1: Identification

1.1. Identification

Product form : Substance
Substance name : Calcium Carbonate
CAS No : 471-34-1
Product code : LC12690
Formula : CaCO3

1.2. Relevant identified uses of the substance or mixture and uses advised against

Use of the substance/mixture : For laboratory and manufacturing use only.
Recommended use : Laboratory chemicals
Restrictions on use : Not for food, drug or household use

1.3. Details of the supplier of the safety data sheet

LabChem Inc
Jackson's Pointe Commerce Park Building 1000, 1010 Jackson's Pointe Court
Zelienople, PA 16063 - USA
T 412-826-5230 - F 724-473-0647
info@labchem.com - www.labchem.com

1.4. Emergency telephone number

Emergency number : CHEMTREC: 1-800-424-9300 or 011-703-527-3887

SECTION 2: Hazard(s) identification

2.1. Classification of the substance or mixture

GHS-US classification

Skin corrosion/irritation Category 2	H315
Serious eye damage/eye irritation Category 2B	H320
Specific target organ toxicity (single exposure) Category 3	H335

Full text of H statements : see section 16

2.2. Label elements

GHS-US labeling

Hazard pictograms (GHS-US) :

GHS07

Signal word (GHS-US) : Warning

Hazard statements (GHS-US) : H315 - Causes skin irritation
H320 - Causes eye irritation
H335 - May cause respiratory irritation

Precautionary statements (GHS-US) : P261 - Avoid breathing dust
P264 - Wash exposed skin thoroughly after handling
P271 - Use only outdoors or in a well-ventilated area
P280 - Wear protective gloves, eye protection
P302+P352 - IF ON SKIN: Wash with plenty of soap and water
P305+P351+P338 - If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P312 - Call a POISON CENTER or doctor/physician if you feel unwell
P332+P313 - If skin irritation occurs: Get medical advice/attention
P337+P313 - If eye irritation persists: Get medical advice/attention
P362+P364 - Take off contaminated clothing and wash it before reuse
P403+P233 - Store in a well-ventilated place. Keep container tightly closed
P405 - Store locked up
P501 - Dispose of contents/container to comply with local, state and federal regulations
If inhaled: Remove person to fresh air and keep comfortable for breathing

2.3. Other hazards

Other hazards not contributing to the classification : None under normal conditions.

2.4. Unknown acute toxicity (GHS US)

Not applicable

SECTION 3: Composition/Information on ingredients

3.1. Substances

Substance type : Mono-constituent

Name	Product identifier	%	GHS-US classification
Calcium Carbonate (Main constituent)	(CAS No) 471-34-1	100	Skin Irrit. 2, H315 Eye Irrit. 2B, H320 STOT SE 3, H335

Full text of hazard classes and H-statements : see section 16

3.2. Mixtures

Not applicable

SECTION 4: First aid measures

4.1. Description of first aid measures

First-aid measures general : Never give anything by mouth to an unconscious person. If you feel unwell, seek medical advice (show the label where possible).

First-aid measures after inhalation : Remove victim to fresh air and keep at rest in a position comfortable for breathing. Call a POISON CENTER or doctor/physician if you feel unwell.

First-aid measures after skin contact : Wash with plenty of soap and water. Wash contaminated clothing before reuse. If skin irritation occurs: Get medical advice/attention.

First-aid measures after eye contact : IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.

First-aid measures after ingestion : Rinse mouth. Do NOT induce vomiting. Obtain emergency medical attention.

4.2. Most important symptoms and effects, both acute and delayed

Symptoms/injuries after inhalation : May cause respiratory irritation.

Symptoms/injuries after skin contact : Causes skin irritation.

Symptoms/injuries after eye contact : Causes eye irritation.

4.3. Indication of any immediate medical attention and special treatment needed

Obtain medical assistance.

SECTION 5: Firefighting measures

5.1. Extinguishing media

Suitable extinguishing media : Foam. Dry powder. Carbon dioxide. Water spray. Sand.

Unsuitable extinguishing media : Do not use a heavy water stream.

5.2. Special hazards arising from the substance or mixture

Fire hazard : Not flammable.

Reactivity : Upon combustion: CO and CO2 are formed. Violent to explosive reaction with (some) acids.

5.3. Advice for firefighters

Firefighting instructions : Use water spray or fog for cooling exposed containers. Exercise caution when fighting any chemical fire. Prevent fire-fighting water from entering environment.

Protection during firefighting : Do not enter fire area without proper protective equipment, including respiratory protection.

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

6.1.1. For non-emergency personnel

Protective equipment : Safety glasses. Gloves. Dust mask.

Emergency procedures : Evacuate unnecessary personnel.

6.1.2. For emergency responders

Protective equipment : Equip cleanup crew with proper protection.

Emergency procedures : Ventilate area.

6.2. Environmental precautions

Prevent entry to sewers and public waters. Notify authorities if liquid enters sewers or public waters.

6.3. Methods and material for containment and cleaning up

Methods for cleaning up : On land, sweep or shovel into suitable containers. Minimize generation of dust. Store away from other materials.

6.4. Reference to other sections

See Heading 8. Exposure controls and personal protection.

SECTION 7: Handling and storage

7.1. Precautions for safe handling

Precautions for safe handling : Wash hands and other exposed areas with mild soap and water before eating, drinking or smoking and when leaving work. Provide good ventilation in process area to prevent formation of vapor. Avoid breathing dust. Use only outdoors or in a well-ventilated area.

Hygiene measures : Wash exposed skin thoroughly after handling.

7.2. Conditions for safe storage, including any incompatibilities

Storage conditions : Keep container tightly closed.

Incompatible products : Strong oxidizers. Strong acids.

Incompatible materials : Sources of ignition. Direct sunlight.

SECTION 8: Exposure controls/personal protection

8.1. Control parameters

Calcium Carbonate (471-34-1)		
OSHA	OSHA PEL (TWA) (mg/m³)	5 mg/m³
NIOSH	NIOSH REL (TWA) (mg/m³)	5 mg/m³

8.2. Exposure controls

Appropriate engineering controls : Emergency eye wash fountains and safety showers should be available in the immediate vicinity of any potential exposure. Ensure good ventilation of the work station.

Personal protective equipment : Safety glasses. Gloves. Dust formation: dust mask.

Hand protection : Wear protective gloves.

Eye protection : Chemical goggles or safety glasses.

Respiratory protection : Dust formation: dust mask.

Other information : Do not eat, drink or smoke during use.

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Physical state : Solid

Appearance : White powder or lumps.

Color : white

Odor : None.

Odor threshold : No data available

pH : No data available

Melting point : 825 °C

Freezing point : No data available

Boiling point : No data available

Flash point : No data available

Relative evaporation rate (butyl acetate=1) : No data available

Flammability (solid, gas) : Non flammable.

Vapor pressure	: No data available
Relative vapor density at 20 °C	: No data available
Relative density	: No data available
Specific gravity / density	: 2.93 g/cm³
Molecular mass	: 100.09 g/mol
Solubility	: Water: 0.00153 g/100ml
Log Pow	: No data available
Auto-ignition temperature	: No data available
Decomposition temperature	: 825 °C
Viscosity, kinematic	: No data available
Viscosity, dynamic	: No data available
Explosion limits	: No data available
Explosive properties	: No data available
Oxidizing properties	: No data available

9.2. Other information

No additional information available

SECTION 10: Stability and reactivity

10.1. Reactivity

Upon combustion: CO and CO2 are formed. Violent to explosive reaction with (some) acids.

10.2. Chemical stability

Stable under normal conditions.

10.3. Possibility of hazardous reactions

Reacts violently with acids.

10.4. Conditions to avoid

Direct sunlight. Extremely high or low temperatures.

10.5. Incompatible materials

Strong acids. Strong oxidizers.

10.6. Hazardous decomposition products

Carbon monoxide. Carbon dioxide.

SECTION 11: Toxicological information

11.1. Information on toxicological effects

Likely routes of exposure	: Inhalation; Skin and eye contact
Acute toxicity	: Not classified

Calcium Carbonate (471-34-1)	
LD50 oral rat	6450 mg/kg
ATE US (oral)	6450.000 mg/kg body weight

Skin corrosion/irritation	: Causes skin irritation.
Serious eye damage/irritation	: Causes eye irritation.
Respiratory or skin sensitization	: Not classified
Germ cell mutagenicity	: Not classified
Carcinogenicity	: Not classified
Reproductive toxicity	: Not classified
Specific target organ toxicity – single exposure	: May cause respiratory irritation.
Specific target organ toxicity – repeated exposure	: Not classified
Aspiration hazard	: Not classified
Potential Adverse human health effects and symptoms	: Based on available data, the classification criteria are not met.

Symptoms/injuries after inhalation : May cause respiratory irritation.
Symptoms/injuries after skin contact : Causes skin irritation.
Symptoms/injuries after eye contact : Causes eye irritation.

SECTION 12: Ecological information

12.1. Toxicity

No additional information available

12.2. Persistence and degradability

Calcium Carbonate (471-34-1)	
Persistence and degradability	Not established.

12.3. Bioaccumulative potential

Calcium Carbonate (471-34-1)	
Bioaccumulative potential	Not established.

12.4. Mobility in soil

No additional information available

12.5. Other adverse effects

Other information : Avoid release to the environment.

SECTION 13: Disposal considerations

13.1. Waste treatment methods

Waste disposal recommendations : Dispose in a safe manner in accordance with local/national regulations.
Ecology - waste materials : Avoid release to the environment.

SECTION 14: Transport information

Department of Transportation (DOT)

In accordance with DOT

Not regulated

SECTION 15: Regulatory information

15.1. US Federal regulations

Calcium Carbonate (471-34-1)	
Listed on the United States TSCA (Toxic Substances Control Act) inventory	
SARA Section 311/312 Hazard Classes	Immediate (acute) health hazard

All components of this product are listed, or excluded from listing, on the United States Environmental Protection Agency Toxic Substances Control Act (TSCA) inventory

This product or mixture does not contain a toxic chemical or chemicals in excess of the applicable de minimis concentration as specified in 40 CFR §372.38(a) subject to the reporting requirements of section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR Part 372.

15.2. International regulations

CANADA

Calcium Carbonate (471-34-1)	
Listed on the Canadian DSL (Domestic Substances List)	
WHMIS Classification	Class D Division 2 Subdivision B - Toxic material causing other toxic effects

EU-Regulations

No additional information available

National regulations

Calcium Carbonate (471-34-1)
Not listed on the Canadian IDL (Ingredient Disclosure List)

15.3. US State regulations

California Proposition 65 - This product does not contain any substances known to the state of California to cause cancer, developmental and/or reproductive harm

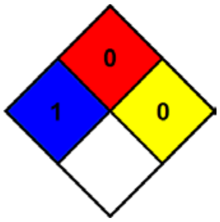
SECTION 16: Other information

Revision date : 12/29/2016
Other information : None.

Full text of H-phrases: see section 16:

H315	Causes skin irritation
H320	Causes eye irritation
H335	May cause respiratory irritation

NFPA health hazard : 1 - Materials that, under emergency conditions, can cause significant irritation.
NFPA fire hazard : 0 - Materials that will not burn under typical dire conditions, including intrinsically noncombustible materials such as concrete, stone, and sand.
NFPA reactivity : 0 - Material that in themselves are normally stable, even under fire conditions.



HMIS III Rating
Health : 1 Slight Hazard - Irritation or minor reversible injury possible
Flammability : 0 Minimal Hazard - Materials that will not burn
Physical : 0 Minimal Hazard - Materials that are normally stable, even under fire conditions, and will NOT react with water, polymerize, decompose, condense, or self-react. Non-Explosives.
Personal protection : E

E - Safety glasses, Gloves, Dust respirator

SDS US LabChem

Information in this SDS is from available published sources and is believed to be accurate. No warranty, express or implied, is made and LabChem Inc assumes no liability resulting from the use of this SDS. The user must determine suitability of this information for his application.

Sodium Carbonate,Anhydrous

SECTION 1 : Identification of the substance/mixture and of the supplier

Product name :	**Sodium Carbonate,Anhydrous**
Manufacturer/Supplier Trade name:	
Manufacturer/Supplier Article number:	**S25539D**

Recommended uses of the product and uses restrictions on use:

Manufacturer Details:

AquaPhoenix Scientific
9 Barnhart Drive, Hanover, PA 17331

Supplier Details:

Fisher Science Education
15 Jet View Drive, Rochester, NY 14624

Emergency telephone number:

Fisher Science Education Emergency Telephone No.: 800-535-5053

SECTION 2 : Hazards identification

Classification of the substance or mixture:

Irritant
Eye irritation, category 2A

Eye Irritation 2

Signal word :Warning

Hazard statements:
Causes serious eye irritation

Precautionary statements:
If medical advice is needed, have product container or label at hand
Keep out of reach of children
Read label before use
Do not eat, drink or smoke when using this product
Wear protective gloves/protective clothing/eye protection/face protection
Wash skin thoroughly after handling
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing
If eye irritation persists get medical advice/attention

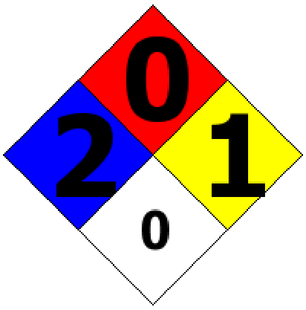
Other Non-GHS Classification:

WHMIS

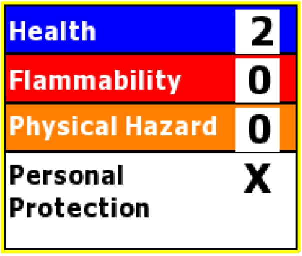
D2B

E

NFPA/HMIS



NFPA SCALE (0-4)



Health	2
Flammability	0
Physical Hazard	0
Personal Protection	X

HMIS RATINGS (0-4)

SECTION 3 : Composition/information on ingredients

Ingredients:		
CAS 497-19-8	Sodium Carbonate, Anhydrous	100 %
		Percentages are by weight

SECTION 4 : First aid measures

Description of first aid measures

After inhalation: Move exposed individual to fresh air. Loosen clothing as necessary and position individual in a comfortable position.Seek medical advice if discomfort or irritation persists.If breathing difficult, give oxygen.

After skin contact: Wash affected area with soap and water. Rinse thoroughly. Seek medical attention if irritation, discomfort or vomiting persists.

After eye contact: Protect unexposed eye. Rinse/flush exposed eye(s) gently using water for 15-20 minutes. Remove contact lens(es) if able to do so during rinsing. Seek medical attention if irritation persists or if concerned.

After swallowing: Rinse mouth thoroughly. Do not induce vomiting. Have exposed individual drink sips of water. Seek medical attention if irritation, discomfort or vomiting persists.

Most important symptoms and effects, both acute and delayed:

Irritation, Nausea,Headache, Shortness of breath.Lachrymator (substance which increases flow of tears).;

Indication of any immediate medical attention and special treatment needed:

If seeking medical attention, provide SDS document to physician.

SECTION 5 : Firefighting measures

Extinguishing media

Suitable extinguishing agents: If in laboratory setting, follow laboratory fire suppression procedures. Use appropriate fire suppression agents for adjacent combustible materials or sources of ignition

For safety reasons unsuitable extinguishing agents:

Special hazards arising from the substance or mixture:

Combustion products may include carbon oxides or other toxic vapors.Thermal decomposition can lead to release of irritating gases and vapors.

Advice for firefighters:

Protective equipment: Use NIOSH-approved respiratory protection/breathing apparatus.

Additional information (precautions): Move product containers away from fire or keep cool with water spray as a protective measure, where feasible.

SECTION 6 : Accidental release measures

Personal precautions, protective equipment and emergency procedures:

Wear protective equipment. Avoid dispersal of dust in the air (i.e., clearing dust surfaces with compressed air). Follow good hygiene procedures when handling chemical materials. Use respiratory protective device against the effects of fumes/dust/aerosol. Keep unprotected persons away. Ensure adequate ventilation.Keep away from ignition sources. Protect from heat.Stop the spill, if possible. Contain spilled material by diking or using inert absorbent. Transfer to a disposal or recovery container.

Environmental precautions:

Prevent from reaching drains, sewer or waterway. Collect contaminated soil for characterization per Section 13

Methods and material for containment and cleaning up:

If in a laboratory setting, follow Chemical Hygiene Plan procedures.Place into properly labeled containers for recovery or disposal. If necessary, use trained response staff/contractor.Absorb and containerize for disposal. Avoid generating dust. Collect solids in powder form using vacuum with (HEPA filter)

Reference to other sections:

SECTION 7 : Handling and storage

Precautions for safe handling:

Follow good hygiene procedures when handling chemical materials. Do not eat, drink, smoke, or use personal products when handling chemical substances. If in a laboratory setting, follow Chemical Hygiene Plan.Use only in well ventilated areas.Avoid generation of dust or fine particulate.Avoid contact with eyes, skin, and clothing. Wash hands after handling. Avoid dispersal of dust in the air (i.e., clearing dust surfaces with compressed air).

Conditions for safe storage, including any incompatibilities:

Store in a cool location. Provide ventilation for containers. Avoid storage near extreme heat, ignition sources or open flame. Store away from foodstuffs. Store away from oxidizing agents.Store in cool, dry conditions in well sealed containers. Keep container tightly sealed.

SECTION 8 : Exposure controls/personal protection

Control Parameters:	No applicable occupational exposure limits
Appropriate Engineering controls:	Emergency eye wash fountains and safety showers should be available in the immediate vicinity of use/handling.Provide exhaust ventilation or other engineering controls to keep the airborne concentrations of vapor or dusts (total/respirable) below the applicable workplace exposure limits (Occupational Exposure Limits-OELs) indicated above.Use under a fume hood
Respiratory protection:	Not required under normal conditions of use. Use suitable respiratory protective device when high concentrations are present. Use suitable respiratory protective device when aerosol or mist is formed. For spills, respiratory protection may be advisable.

Protection of skin:	The glove material has to be impermeable and resistant to the product/ the substance/ the preparation being used/handled.Selection of the glove material on consideration of the penetration times, rates of diffusion and the degradation.
Eye protection:	Safety glasses with side shields or goggles.
General hygienic measures:	The usual precautionary measures are to be adhered to when handling chemicals. Keep away from food, beverages and feed sources. Immediately remove all soiled and contaminated clothing. Wash hands before breaks and at the end of work. Do not inhale gases/fumes/dust/mist/vapor/aerosols. Avoid contact with the eyes and skin.

SECTION 9 : Physical and chemical properties

Appearance (physical state,color):	White solid	**Explosion limit lower**: **Explosion limit upper**:	Not determined Not determined
Odor:	Odorless	**Vapor pressure**:	1 mmHg @ 865C
Odor threshold:	Not determined	**Vapor density**:	Not determined
pH-value:	Not determined	**Relative density**:	Not determined
Melting/Freezing point:	851C	**Solubilities**:	Partly soluble in water. 220 g/l at 20C
Boiling point/Boiling range:	1600 C @760mmHg	**Partition coefficient (n-octanol/water)**:	Not determined
Flash point (closed cup):	Not determined	**Auto/Self-ignition temperature**:	Not determined
Evaporation rate:	Not determined	**Decomposition temperature**:	Not determined
Flammability (solid,gaseous):	Not determined	**Viscosity**:	a. Kinematic:Not determined b. Dynamic: Not determined
Density: Not determined **Specific Gravity:**2.53 **Additional property::**Hygroscopic.			

SECTION 10 : Stability and reactivity

Reactivity:
Chemical stability: No decomposition if used and stored according to specifications.
Possible hazardous reactions:
Conditions to avoid: Store away from oxidizing agents, strong acids or bases.
Incompatible materials: Strong oxidizers, strong acids, fluorine
Hazardous decomposition products: Carbon oxides (CO, CO2).Oxides of sodium

SECTION 11 : Toxicological information

Acute Toxicity:		
Oral:	4090mg/kg	LD50 oral-rat:

Inhalation:	2300 mg/m3	LC50 (2h) Rat
Dermal:	2210 mg/kg	LD50 Mouse
Chronic Toxicity: No additional information.		
Corrosion Irritation:		
Ocular:	Section 2	Classified as an eye irritant
Sensitization:		No additional information.
Single Target Organ (STOT):		No additional information.
Numerical Measures:		No additional information.
Carcinogenicity:		No additional information.
Mutagenicity:		No additional information.
Reproductive Toxicity:		No additional information.

SECTION 12 : Ecological information

Ecotoxicity

Fish: LC50 (96h) L. macrochius: 300 mg/l

Fish: LC50 (96h) P. promelas (various age groups): 310-1220 mg/l

Crustacea - LC50; Species: D. magna : 265 mg/L

Persistence and degradability: Readily degradable in the environment.
Bioaccumulative potential: No bioaccumulation
Mobility in soil:
Other adverse effects:

SECTION 13 : Disposal considerations

Waste disposal recommendations:

Product/containers must not be disposed together with household garbage. Do not allow product to reach sewage system or open water.It is the responsibility of the waste generator to properly characterize all waste materials according to applicable regulatory entities (US 40CFR262.11). Consult federal state/ provincial and local regulations regarding the proper disposal of waste material that may incorporate some amount of this product.

SECTION 14 : Transport information

UN-Number

Not Regulated.

UN proper shipping name

Not Regulated.

Transport hazard class(es)
Packing group:Not Regulated
Environmental hazard:
Transport in bulk:
Special precautions for user:

SECTION 15 : Regulatory information

United States (USA)

SARA Section 311/312 (Specific toxic chemical listings):

None of the ingredients is listed

SARA Section 313 (Specific toxic chemical listings):

None of the ingredients is listed

RCRA (hazardous waste code):

None of the ingredients is listed

TSCA (Toxic Substances Control Act):

All ingredients are listed.

CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act):

None of the ingredients is listed

Proposition 65 (California):

Chemicals known to cause cancer:

None of the ingredients is listed

Chemicals known to cause reproductive toxicity for females:

None of the ingredients is listed

Chemicals known to cause reproductive toxicity for males:

None of the ingredients is listed

Chemicals known to cause developmental toxicity:

None of the ingredients is listed

Canada

Canadian Domestic Substances List (DSL):

All ingredients are listed.

Canadian NPRI Ingredient Disclosure list (limit 0.1%):

None of the ingredients is listed

Canadian NPRI Ingredient Disclosure list (limit 1%):

497-19-8 Sodium carbonate

SECTION 16 : Other information

This product has been classified in accordance with hazard criteria of the Controlled Products Regulations and the SDS contains all the information required by the Controlled Products Regulations.Note:. The responsibility to provide a safe workplace remains with the user.The user should consider the health hazards and safety information contained herein as a guide and should take those precautions required in an individual operation to instruct employees and develop work practice procedures for a safe work environment.The information contained herein is, to the best of our knowledge and belief, accurate.However, since the conditions of handling and use are beyond our control, we make no guarantee of results, and assume no liability for damages incurred by the use of this material.It is the responsibility of the user to comply with all applicable laws and regulations applicable to this material.

GHS Full Text Phrases:

Abbreviations and acronyms:

IMDG: International Maritime Code for Dangerous Goods
IATA: International Air Transport Association
GHS: Globally Harmonized System of Classification and Labelling of Chemicals
ACGIH: American Conference of Governmental Industrial Hygienists
CAS: Chemical Abstracts Service (division of the American Chemical Society)
NFPA: National Fire Protection Association (USA)
HMIS: Hazardous Materials Identification System (USA)
WHMIS: Workplace Hazardous Materials Information System (Canada)
DNEL: Derived No-Effect Level (REACH)
PNEC: Predicted No-Effect Concentration (REACH)
CFR: Code of Federal Regulations (USA)
SARA: Superfund Amendments and Reauthorization Act (USA)
RCRA: Resource Conservation and Recovery Act (USA)
TSCA: Toxic Substances Control Act (USA)
NPRI: National Pollutant Release Inventory (Canada)
DOT: US Department of Transportation

Effective date : 12.12.2014
Last updated : 03.19.2015

SIGMA-ALDRICH

sigma-aldrich.com

Material Safety Data Sheet

Version 5.1
Revision Date 10/09/2012
Print Date 03/26/2014

1. PRODUCT AND COMPANY IDENTIFICATION

Product name : Zeolite

Product Number : 96096
Brand : Sigma

Supplier : Sigma-Aldrich
3050 Spruce Street
SAINT LOUIS MO 63103
USA
Telephone : +1 800-325-5832
Fax : +1 800-325-5052
Emergency Phone # (For both supplier and manufacturer) : (314) 776-6555
Preparation Information : Sigma-Aldrich Corporation
Product Safety - Americas Region
1-800-521-8956

2. HAZARDS IDENTIFICATION

Emergency Overview

OSHA Hazards
Irritant

Target Organs

Lungs, Bone

GHS Classification
Acute toxicity, Inhalation (Category 5)
Acute toxicity, Dermal (Category 5)
Specific target organ toxicity - single exposure (Category 3)

GHS Label elements, including precautionary statements

Pictogram

Signal word Warning

Hazard statement(s)

H313 + H333	May be harmful in contact with skin or if inhaled.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.

HMIS Classification

Health hazard:	2
Flammability:	0
Physical hazards:	0

NFPA Rating

Health hazard:	2
Fire:	0
Reactivity Hazard:	0

Potential Health Effects

Inhalation	May be harmful if inhaled. Causes respiratory tract irritation.
Skin	May be harmful if absorbed through skin. Causes skin irritation.
Eyes	Causes eye irritation.
Ingestion	May be harmful if swallowed.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Component	Concentration
Zeolites crystalline alumiosilicates, composed of silica (SiO2) and alumina (Al2O3), in various proportions plus metallic oxides. Pr	
CAS-No. 1318-02-1 EC-No. 215-283-8	-

4. FIRST AID MEASURES

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Flush eyes with water as a precaution.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

5. FIREFIGHTING MEASURES

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

Special protective equipment for firefighters
Wear self contained breathing apparatus for fire fighting if necessary.

Hazardous combustion products
Hazardous decomposition products formed under fire conditions. - Nature of decomposition products not known.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions
Use personal protective equipment. Avoid dust formation. Avoid breathing vapors, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas. Avoid breathing dust.

Environmental precautions
Do not let product enter drains.

Methods and materials for containment and cleaning up
Pick up and arrange disposal without creating dust. Sweep up and shovel. Keep in suitable, closed containers for disposal.

7. HANDLING AND STORAGE

Precautions for safe handling
Avoid contact with skin and eyes. Avoid formation of dust and aerosols.
Provide appropriate exhaust ventilation at places where dust is formed. Normal measures for preventive fire protection.

Conditions for safe storage
Keep container tightly closed in a dry and well-ventilated place.

hygroscopic

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Contains no substances with occupational exposure limit values.

Personal protective equipment

Respiratory protection
For nuisance exposures use type P95 (US) or type P1 (EU EN 143) particle respirator.For higher level protection use type OV/AG/P99 (US) or type ABEK-P2 (EU EN 143) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Hand protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Immersion protection
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: > 480 min
Material tested:Dermatril® (Aldrich Z677272, Size M)

Splash protection
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: > 30 min
Material tested:Dermatril® (Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 873000, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an Industrial Hygienist familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Eye protection
Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin and body protection
impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Hygiene measures
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance

Form	solid
Colour	no data available

Safety data

pH	no data available
Melting point/freezing point	no data available
Boiling point	no data available
Flash point	not applicable
Ignition temperature	no data available
Autoignition	no data available

temperature	
Lower explosion limit	no data available
Upper explosion limit	no data available
Vapour pressure	no data available
Density	no data available
Water solubility	no data available
Partition coefficient: n-octanol/water	no data available
Relative vapour density	no data available
Odour	no data available
Odour Threshold	no data available
Evaporation rate	no data available

10. STABILITY AND REACTIVITY

Chemical stability
Stable under recommended storage conditions.

Possibility of hazardous reactions
no data available

Conditions to avoid
Avoid moisture.

Materials to avoid
Strong acids, Strong bases, Hydrogen fluoride, Chlorine trifluoride, Ethylene oxide, Halogenated hydrocarbon, Oxygen difluoride, Sodium nitrate, Vinyl compoundsStrong acids, Strong oxidizing agents

Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. - Nature of decomposition products not known.
Other decomposition products - no data available

11. TOXICOLOGICAL INFORMATION

Acute toxicity

Oral LD50
LD50 Oral - rat - > 10,000 mg/kg

Inhalation LC50
Dermal LD50
LD50 Dermal - rabbit - > 2,000 mg/kg

Other information on acute toxicity
no data available

Skin corrosion/irritation
Skin - Human - No skin irritation

Serious eye damage/eye irritation
Eyes - rabbit - No eye irritation

Respiratory or skin sensitization
no data available

Germ cell mutagenicity

Genotoxicity in vitro - Human - lymphocyte
Cytogenetic analysis

Genotoxicity in vivo - mouse - Intraperitoneal
Cytogenetic analysis

Carcinogenicity

This product is or contains a component that is not classifiable as to its carcinogenicity based on its IARC, ACGIH, NTP, or EPA classification.

IARC:	3 - Group 3: Not classifiable as to its carcinogenicity to humans (Zeolites crystalline alumiosilicates, composed of silica (SiO2) and alumina (Al2O3), in various proportions plus metallic oxides. Pr)
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

no data available

Teratogenicity

no data available

Specific target organ toxicity - single exposure (Globally Harmonized System)
Inhalation - May cause respiratory irritation.

Specific target organ toxicity - repeated exposure (Globally Harmonized System)
no data available

Aspiration hazard
no data available

Potential health effects

Inhalation	May be harmful if inhaled. Causes respiratory tract irritation.
Ingestion	May be harmful if swallowed.
Skin	May be harmful if absorbed through skin. Causes skin irritation.
Eyes	Causes eye irritation.

Signs and Symptoms of Exposure
prolonged or repeated exposure can cause:, Damage to the lungs.
Cough, Difficulty in breathing, Gastrointestinal disturbance, prolonged or repeated exposure can cause:, Damage to the lungs., To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Synergistic effects
no data available

Additional Information
RTECS: ZG6800000

12. ECOLOGICAL INFORMATION

Toxicity

Persistence and degradability
no data available

Bioaccumulative potential

no data available

Mobility in soil
no data available

PBT and vPvB assessment
no data available

Other adverse effects

no data available

13. DISPOSAL CONSIDERATIONS

Product
Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods

IMDG
Not dangerous goods

IATA
Not dangerous goods

15. REGULATORY INFORMATION

OSHA Hazards
Irritant

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
Acute Health Hazard

Massachusetts Right To Know Components
No components are subject to the Massachusetts Right to Know Act.

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Zeolites crystalline alumiosilicates, composed of silica (SiO2) and alumina (Al2O3), in various proportions plus metallic oxides. Pr	1318-02-1	

New Jersey Right To Know Components

	CAS-No.	Revision Date
Zeolites crystalline alumiosilicates, composed of silica (SiO2) and alumina (Al2O3), in various proportions plus metallic oxides. Pr	1318-02-1	

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

Further information

MATERIAL SAFETY DATA SHEET

PRODUCT **APATITE II**

COMPOSITION	Apatite II $[Ca_{10-x}Na_x(PO_4)_{6-x}(CO_3)_x(OH)_2$ where $x < 1]$, produced from fish bones (U.S. Patent #6,217,775)
APPEARANCE & FORM	Granular, various sizes from powder to gravel
PACKAGING	Bulk
TOXICITY	Ingestion-Nil Eye and skin contact-Nil Inhalation- Classified as nuisance dust only
CORROSION PROPERTIES	Non-corrosive
FIRE RISK	Low. Combustible when subjected to extreme heat
EXPLOSION RISK	None
HANDLING PROCEDURES	When being handled the dust can be a nuisance. This can be improved by extraction or ventilation. No smoking.
PROTECTIVE CLOTHING	Overalls, dust mask, and eye protection if necessary
STORAGE CONDITIONS	Should be stored at ambient temperature in dry metal or concrete bins.

FIRST AID REQUIREMENTS

EYE CONTACT:	Flush eyes with water. Irritating but does not injure eye tissue.
INHALATION:	No hazard under normal conditions. Move victim to fresh air area. Call doctor if breathing is irregular. Low order of toxicity.
SKIN CONTACT:	Skin may become dry from the dust. Wash thoroughly after contact, with soap if available. Low order of toxicity.
INGESTION:	No hazard. If ingested, give large amounts of water. Minimal toxicity.

DISPOSAL OF SPILLAGE AND WASTE

Shut off source without hazard if possible. Sweep up spilled material and place in container to be recycled.

SUPPLEMENTAL INFORMATION

These materials are made from naturally occurring, benign fish bone products and may contain naturally occurring microorganisms. Proper precautions are advised to prevent infection of open wounds. Avoid inhaling excessive amounts of dust. Avoid eye contact. Observe the proper hygiene practices necessary to prevent health hazards from any naturally occurring substance such as soil, bark, etc. Wash hands with soap and water after handling.

The information contained in this MSDS is provided without warranty of any kind, expressed or implied. The information contained here is made available solely for the consideration, investigation and verification by the original recipient. Users should consider this information only as a supplement to other information gathered by or available to them. Users should make independent determinations of the suitability and completeness of information from all sources to assure proper use and disposal of these materials for the safety and health of employees, customers and environment. This hazard information is not a substitute for risk assessment under actual conditions of use. Users have the responsibility to keep currently informed on chemical hazard information, to design and update their own programs, and to comply with all applicable national, federal, state, and local laws and regulations regarding safety, occupational health, right to know, and environmental protection.

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Rev. 1, 10.2009

Appendix D
Treatability Laboratory Operating Procedures

Study-Specific Treatability Test Procedures

The following section describes equipment and methods appropriate to performing the titration and bucket testing activities described in Section 4.4. While the general method of column testing is explained in the text, the design of the column testing will depend on the results of the titration and microcosm testing.

The information presented below is intended to supplement the general treatability test lab SOPs. The equipment specifications and safety protocols may vary, but the general methods for performing titration and bucket tests are described herein. Specifics of reagents, timing, and analytical testing are provided in Section 4.4.

Titration Testing

Equipment required for titration testing includes the following:

- One half liter of selected reagents,
- One liter of impacted groundwater,
- One or two titration columns, graduated,
- Distilled water,
- Plastic containers for IDW,
- Glassware: 500 ml beakers,
- Magnetic stirring plate and pellets,
- pH meter,
- Dissolved oxygen meter,
- Ferric/ferrous iron test kits and colorimeter,
- H2S meter, and
- ORP meter.

The procedure for titration tests is as follows.

- Before commencing work, review task hazard analysis (THA) for appropriate PPE and safety precautions and review MSDSs for reagents (Appendix A).
- Set-up test stand in in well ventilated area, under fume hood or outside.
- Monitor H_2S continuously during testing.
- Fill beakers to 200 ml with test water. Test for baseline pH and ORP.
- Put beaker on stirring plate and add magnetic pellet. Test stirring plate and pellet to be sure they are working
- If strong bases are received as a concentrated solution, dilute with distilled water to 10% solution.
- FB-H is received as a 10% solution. Be sure FB-H is at least 65°F for use. Be sure FB-H is well agitated before use.
- Fill titration column, note fill mark.
- Begin adding reagent in 5 to 10 mL doses, allow mixing for 1 or 2 minutes, check pH and ORP.
- Continue adding reagent in 5 to 10 ml doses until pH > 6 or ORP becomes -50 mV or lower.

- Note presence of precipitates as titration proceeds.
- After pH reaches 6.0 or ORP reaches -50, let beaker stand for 1 hour and collect samples for laboratory analysis.
- Resume titration until ORP reaches – 200 mV and then resample.
- Laboratory analysis of liquid samples will include total metals, dissolved metals, pH, and ORP and may include analysis of sulfate/sulfide and Iron II/III.
- Samples may include samples of precipitate for total metals and other species to establish mass balance on reagents deemed appropriate for further testing.
- Place testing residuals in plastic containers, label the containers, and arrange for disposal taking care not to mix waste from incompatible reagents.

Microcosm Testing

Specialized equipment and materials for microcosm (bucket) testing activities is as follows:

- Specified dose of selected reagents,
- One 50-pound bag of clean sand,
- 100 pounds of site soil (3 five-gallon buckets, saturated soil from impacted area in downgradient areas or source area soil),
- Ten gallons of impacted groundwater from the site,
- Five 1-gallon buckets with lids,
- Five tap-style spigots with gaskets,
- Five sturdy plastic mixing spoons,
- 40 feet of 3/8 inch plastic tubing,
- PVC pipe and activated carbon to make custom filter for vent tubing,
- Five 3/8-inch hose barbs (large flat tray, or several smaller trays to double contain buckets),
- Duct tape, quick ties, sharpies, laboratory notebooks,
- Sample bottles,
- THA for small batch blending,
- PPE (Tyvek® clothing, safety glasses, splash shield, gloves),
- H_2S meter,
- ORP meter,
- DO meter,
- pH meter, and
- Scale accurate to +/- 0.5 grams.

Review the HASP for site constituents, the small batch blending THA and MSDSs for the reagents. Go over health and safety issues before starting work. Blending will require two people. One person will do the blending while the second observes and operates the H_2S and PID meters. The general procedure for bucket testing is as follows:

- Install spigot assembly on buckets and test for leaks with clean water. Label buckets with sharpie for each regent.

- Weigh out site soil and reagent doses. Approximately 10 pounds of soil will be used per test. Reagent dosing will vary but typically will be in the range of 0.5 to 1 pound.
- Place sand layer in bottom of bucket to level approximately 1 inch above spigot.
- Blend reagent and site soil in approximately one third volumes using plastic utensil. Blend until material is uniform in color and texture. Break-up any clumps that may form.
- Place blended material in one third increments into bucket with spigot assembly. Lightly compact each 1/3 addition.
- Make sure spigot is closed.
- Place impacted groundwater in graduated beaker. Slowly add groundwater to bucket of blended material. Apply water at various points, not just in one spot. Continue adding water until free water is visible at top of blended material. Install lid. Wait one hour and add more water if necessary so that water is just visible at top of soil. Record total volume of water added and replace lid.
- Place buckets in heated area (ideally 55-75^{0}F).
- Place plastic tray/spill pad under buckets to provide drip/spill containment. Containment capacity must exceed the volume of water in the associated buckets.
- Place lids on buckets. Install 3/8-inch vent tubes on top of buckets, run vent tubes to fume hood or outdoor area free from pedestrian traffic.
- Prepare a control test that contains no reagents. Use the same procedures, including blending of soil.

AECOM
Remediation Department
Standard Operating Procedure (SOP)

Task	Batch and Column Experiments for Removing Contaminants from Groundwater
Project or Lab Name and Number	D-116
Additional and Safety Information	The following JSAs must also be read and signed before performing this task: *Column JSA* The following SDSs must be read before performing this task: dependent on the contaminate of concern and the amendments used Qualified individuals to teach this task include: Francisco Barajas and Rachel Watkins

1.0 Batch Reactor Experiment

Amendments of interest are tested for the removal capability of contaminants of concern. The reactors containers could be made of high-density polyethylene or glass, depending on the type of media and contaminant(s) of concern. Within the containers, varying percentages of amendments are added to either site groundwater, site soil, purchased soil or sand. Groundwater is added to the soil and amendment mixture, tightly capped and shaken thoroughly. Each reactor is shaken daily, but otherwise left undisturbed, until samples are collected and analyzed for the contaminant of concern. Biological batch reactors (microcosms) will require a set of sterile controls to determine contaminant losses that are not due to biodegradation. Water controls may also be used to isolate losses due to diffusion out of the reactor bottle.

Note care should be taken to not use materials that would either contaminate the samples for analyses or be incompatible with the contaminate of concern.

1. Label bottles with sample ID and amendment, soil and water quantities.
2. Weigh all amendments into a weigh boat and pour into each reactor. Confirm the amendments do not need to be ground, sieved, or dissolved in water first. Record the weights.
3. Weigh all soils into a weigh boat and pour into each reactor. Confirm the soils do not need to be ground or sieved first. Record the weights.
4. Add homogenized groundwater to each reactor. Record the weights.
5. Cap and shake thoroughly.
6. Shake daily until sampling for contaminants of concern. If needed, place reactors on a shaker table to continuously mix at a fix speed.

2.0 Column Experiment

Amendment and soil mixtures that perform the best during the batch reactor will be tested using a column set-up over a set duration of time or until break-through has been achieved. For this experiment, both the amendment and soil mixture, along with the groundwater need to be prepared. A multi-channel peristaltic pump will be set up to deliver water for up to six columns, and the columns may be assembled for up-flow or down-flow direction. Columns will be packed by adding the solid media at different height intervals in order to achieve a uniform bulk density through the height of the columns. In some cases, laboratory distilled deionized water may be used to fully saturate the column media in order to displace any air in the pore space. Once fully saturated, and after leak and flow checks, the columns can begin being fed groundwater.
Note: care should be taken to not use materials that would either contaminate the samples for analyses or be incompatible with the contaminate of concern.

Solids and Ground Water Preparation

1. Homogenize the ground water into a single drum if possible. If the water is stored in multiple carboys, shake the carboys and pour equal amounts into the drum. Determine if any spiking should be performed. If the water is spiked, only add some of the final amount of water to the drum, add the spike, then the remaining portion of the water to aid with mixing.
2. Add a tracer (such as a dye or potassium bromate) to determine breakthrough times of the groundwater through the column if necessary. Confirm this analyte will not interfere with the experiment or analyses.
3. Homogenize the soil, and sieve if necessary.
4. Weigh the soil into an appropriate container(s). Record the weight.
5. Weigh each amendment and add to the appropriate amount of soil. Confirm the amendment does not need to be ground or sieved first. Record the weights.
6. If necessary, add a minimal amount of deionized water to the soil and amendment mixture to aid in homogenization. This is especially important when using large particle amendments such as biochar. Record the amount of deionized water added.
7. Perform porosity tests
    - Place the fill media in separate graduated beakers and dry in a 55ºC oven overnight.
    - Note the volume of the dried fill media for each beaker.
    - Slowly add water to each beaker until the water comes just to the top of the fill media. Record the total volume of water added to each beaker.
8. Perform hydraulic conductivity tests

- Place the fill media into a large cylinder with graduations, with a bottom outlet spout that can be closed off with a stainless-steel nut.
- With the stainless-steel nut securely in place, fill the cylinder with enough water to clearly distinguish between a settled layer of solids and liquid.
- Once the demarcation is clear between the water and solids, note the levels for each.
- Remove the stainless-steel nut and start a timer simultaneously. Note changes in the water and solids level over time, with intervals being dependent on the speed of water flow through the fill media. Continue until the apparatus runs dry.

Assemble columns

1. Determine if a mid-point sampling port is needed.
2. Assemble one end of each of the columns based on the manufacturer’s instructions.
3. Properly seat the coarse and fine filter. If making the columns with PVC piping, use glass wood and glass beads as the coarse and fine filter. Record the weight.
4. Pack the fill mixture of soil and amendment into the column(s). Record the weight.
5. Close the other end of the column(s). Record the weight.
6. Secure the columns on the support stand and attach the appropriate outlet tubing.
7. Determine the direction of flow through the column. Typically, columns are fed with the groundwater from the bottom up, to ensure saturation of the media.
8. Hook up the column(s) to the pump and begin to prime the columns with deionized water.
9. Perform leak and flow checks.

Assemble pumps

1. Determine the flow rate needed based on the porosity and hydraulic conductivity.
2. Determine the type of peristaltic pump to use – speed, single vs multi-channel.
3. Assemble the pump per the manufacturer’s instructions, using the tubing size that best achieves the desired flow rates.
4. If the desired flow rate cannot be achieved, place a needle valve on the back end of the column outlet to slow the flow.

Start-up

1. Begin feeding laboratory water to fully saturate the column or start with groundwater through the peristaltic pump to the column(s).

2. Place the outlet lines from each column into pre-weighed beakers. Monitor the flow rates hourly at the beginning, then daily over the first few days. Record the time and effluent + beaker weights.
3. Take hourly samples of the effluent and measure to determine groundwater breakthrough.
4. Monitor for leaks, clogs and the influent drum level frequently.
5. To collect samples, place a new bottle into each effluent catch beaker.
6. Measure pH, ORP, DO and/or electric conductivity or any other parameter as needed prior to sending out samples for analyses.

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