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November 25, 2020

Andrew Wheeler
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460

Submitted electronically

Subject: **Request for site-specific alternative deadline to initiate closure of CCR surface impoundment pursuant to 40 CFR 257.103(f)(2)**
Burlington Generating Station
Interstate Power and Light Company
Burlington, Iowa

Mr. Wheeler:

On behalf of Interstate Power and Light Company (IPL), Alliant Energy is submitting the enclosed request for a site-specific alternative deadline to initiate closure of a CCR surface impoundment pursuant to 40 CFR 257.103(f)(2). The enclosed demonstration includes documentation that the criteria in paragraphs §257.103(f)(2)(i) through (iv) have been met and that the surface impoundments will complete closure no later than October 17, 2023.

We appreciate EPA's consideration of this request and the assistance from EPA staff during the development of the enclosed information. Please contact me at (608) 458-3853 or jeffreymaxted@alliantenergy.com if you have any questions or need additional information.

Sincerely,

Jeff Maxted
Manager – Environmental Services
Alliant Energy

Enclosures

Cc: Kirsten Hillyer, Frank Behan, Richard Huggins – U.S. EPA
John Watts, Jeff Hanson, Marney Hoefer – Alliant Energy

Application for Site-Specific Alternative Deadline to Initiate Closure of CCR Surface Impoundments

Burlington Generating Station
4282 Sullivan Slough Road
Burlington, Iowa 52601

Prepared for:

Interstate Power and Light Company
4282 Sullivan Slough Road
Burlington, Iowa 52601

SCS ENGINEERS

25219168.00 | November 24, 2020

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EXECUTIVE SUMMARY

The Interstate Power and Light Company (IPL) Burlington Generating Station (BGS) is a steam-electric generating station located south of Burlington, Iowa. IPL will end coal-fired operations at BGS by December 31, 2021, and operate the boiler with natural gas after coal-fired operations cease as required by a July 15, 2015 Consent Decree.

IPL currently operates one coal-fired boiler at BGS and uses four existing coal combustion residual (CCR) surface impoundments to manage CCR and non-CCR wastestreams. Each of the four CCR surface impoundments are less than 40 acres in size and all are unlined. The surface impoundments must close due to the requirements of 40 CFR 257.101(a) and (b)(1)(i).

IPL is submitting this application to demonstrate absence of alternative capacity for managing CCR and non-CCR wastestreams and is requesting U.S. Environmental Protection Agency (USEPA) approval to continue disposal of these wastestreams beyond April 11, 2021, as allowed by §257.103(f)(2). With USEPA approval, IPL will cease placing CCR and non-CCR wastestreams in the CCR surface impoundments by December 31, 2021, and will complete closure of the four unlined CCR surface impoundments by October 17, 2023.

No existing alternate disposal capacity is available on or off site for managing an average 3.7 million gallons per day (MGD) of CCR and non-CCR wastestreams generated at BGS.

- All existing, suitable space for treatment and disposal of these wastestreams on IPL property is occupied by existing CCR surface impoundments or other infrastructure necessary to BGS operations.
- No existing conveyance system is available to discharge these wastestreams offsite for treatment and disposal.
- Hauling these wastestreams off site for treatment and disposal is not feasible due to waste volume and the high number of trucks/truckloads required to manage the volume.
- No existing temporary facilities are available at BGS, nor is there adequate space on site to deploy temporary/portable treatment capacity.

IPL has provided certification of compliance with all other requirements of the CCR Rule as of the date of application submittal, including the requirement to conduct any necessary corrective action, as required in §257.103(f)(2)(iii). Lithium and molybdenum have been detected at statistically significant levels (SSL) above the groundwater protection standard (GPS) in samples from more than one downgradient monitoring well at BGS. IPL has completed an Assessment of Corrective Measures and recently completed an addendum to the assessment. IPL is working to address these existing groundwater impacts through the CCR Rule Corrective Action process. IPL is actively designing a remedy that includes changing source water, redirecting low volume wastewaters, and closing the CCR surface impoundments. Pursuant to §257.103(f)(2)(v)(B), IPL has prepared a risk mitigation plan to address groundwater impacts. As required in §257.103(f)(2)(ii), potential risks to human health and the environment during continued operation of the CCR surface impoundments are adequately mitigated.

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1.0 INTRODUCTION AND PURPOSE

The Interstate Power and Light Company (IPL) Burlington Generating Station (BGS) is a steam-electric generating station located south of Burlington, Iowa. The station operates one coal-fired boiler (Unit 1) and uses four coal combustion residual (CCR) surface impoundments to manage CCR and non--CCR wastestreams generated by BGS operations. The four CCR surface impoundments at BGS include:

- BGS Ash Seal Pond (existing CCR surface impoundment)
- BGS Main Ash Pond (existing CCR surface impoundment)
- BGS Economizer Ash Pond (existing CCR surface impoundment)
- BGS Upper Ash Pond (existing CCR surface impoundment)

All four of the existing CCR surface impoundments are subject to the USEPA *Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule*, dated April 17, 2015 (USEPA, 2015), and subsequent amendments. Specifically, the amended Final Rule *"A Holistic Approach to Closure Part A: Deadline To Initiate Closure"* that became effective September 28, 2020. All four of the impoundments are unlined and less than 40 acres in size. Pursuant to 40 CFR §257.101(a), the impoundments must cease receiving CCR and non-CCR wastestreams no later than April 11, 2021, unless the facility complies with the alternative closure provisions of §257.103.

With this Application, IPL is requesting a new site-specific alternative deadline to initiate closure of the BGS CCR surface impoundments pursuant to §257.103(f)(2). USEPA approval of a new site-specific alternative closure deadline allows CCR surface impoundments to continue to receive CCR and/or non-CCR wastestreams if the facility will cease operation of the coal-fired boiler(s) and complete closure of the impoundments by October 17, 2023, for impoundments that are 40 acres or smaller, and the facility must continue to use the CCR surface impoundments due to the absence of alternative disposal capacity both on and off-site prior to ceasing coal-fired operations.

Under a July 15, 2015, Consent Decree (US, 2015), IPL is required to end coal-fired operations and either retire Unit 1 or convert to natural gas operations no later than December 31, 2021. As discussed further in this Application, IPL plans to meet this requirement by operating Unit 1 with natural gas instead of coal as fuel after the cessation of coal-fired operations at BGS. Further, as demonstrated below, there is currently no alternative disposal capacity on or off-site that can be used to manage the CCR and non-CCR wastestreams generated at BGS.

Pursuant to 40 CFR §257.103(f)(2), IPL requests USEPA approval to continue receiving CCR and non-CCR wastes after April 11, 2021. IPL will cease placement of CCR and non-CCR wastes by December 31, 2021, following permanent cessation of a coal-fired boiler by a date certain, and will complete closure of the existing CCR surface impoundments no later than October 17, 2023.

2.0 FACILITY INFORMATION AND BACKGROUND

2.1 FACILITY INFORMATION

BGS is owned and operated by IPL, a subsidiary of Alliant Energy Corporation.

Site Location:	Interstate Power and Light Company Burlington Generating Station 4282 Sullivan Slough Road Burlington, IA 52601 USEPA EPA Registry ID: 110000415355
Project Contact:	Jeff Maxted (Alliant Energy Corporate Services) Manager – Environmental Services, Generation Operations Support 4902 N Biltmore Lane Madison, WI 53718 (608) 458-3853 jeffreymaxted@alliantenergy.com
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2.2 BACKGROUND

BGS is located along the west bank of the Mississippi River, about 5 miles south of the City of Burlington, in Des Moines County, Iowa (**Figure 1**). The BGS site is approximately 70 acres and began operations in 1968. Currently the steam-electric generating facility includes a single coal-fired unit with a nameplate rating of 212 megawatts (MW). (Hard Hat, 2018). Significant site features that support BGS operations include:

- Substation
- Coal stockpile
- Coal runoff pond
- Four CCR units (all are unlined existing CCR surface impoundments each less than 40 acres)
- One surface impoundment (Lower Pond) that is not classified as a CCR Unit.

The four CCR surface impoundments are monitored using a multi-unit groundwater monitoring system. A map showing the CCR surface impoundments and all background (or upgradient) and downgradient monitoring wells with identification numbers for the CCR groundwater monitoring program is provided as **Figure 2**.

3.0 DEMONSTRATION FOR CESSATION OF COAL-FIRED BOILERS

IPL is requesting USEPA approval to continue placing wet-handled CCR and non-CCR wastestreams in the CCR surface impoundments at BGS after April 11, 2021, and then complete closure of the CCR surface impoundments no later than October 17, 2023. The following text and supporting information is provided to document that the requirements in 40 CFR §257.103(f)(2)(i) through (iv) have been met.

3.1 ALTERNATIVE DISPOSAL CAPACITY ASSESSMENT

To demonstrate that no alternative disposal capacity is currently available on- or off-site as required by 40 CFR 257.103(f)(2)(i), information about the wastestreams generated at BGS that are managed using the CCR surface impoundments is provided below along with a discussion of existing alternate disposal capacity.

BGS generates the following CCR and non-CCR wastestreams during plant operations. These wastestreams are wet handled or are wastewaters managed within the on-site CCR surface impoundments. A water balance diagram representing these wastestreams is provided as **Figure 6**.

CCR

- Bottom ash and sluice water – On average 0.53 million gallons per day (MGD) of bottom ash sluice water is discharged to the Main Ash Pond along with bottom ash. Bottom ash is stored in the Main Ash Pond and recovered for off-site beneficial use as a raw feed for concrete production. Sluice water from the Main Ash Pond is discharged to the Upper Ash Pond (Alliant Energy, 2020).

- Economizer ash and sluice water – On average 2.87 MGD of economizer ash sluice water is discharged to the Economizer Pond along with economizer ash. Economizer ash is dredged on an as needed basis and thin spread in upland areas within the Economizer Pond. Sluice water from the Economizer Pond is discharged to the Upper Ash Pond.

Non-CCR

- Ash seal water – On average the ash seal system discharges 0.684 MGD to the Main Ash Pond.

- Boiler makeup and blowdown – Boiler makeup and blowdown water (0.034 MGD) along with rinsate water from chemical cleaning (Average of 0.02 MGD) are discharged to the Main Ash Pond.

- Water treatment area floor drains and reverse osmosis (RO) system reject – Approximately 0.11 MGD of wastewater collected by floor drains in the wastewater treatment area and RO system reject are directed to the Economizer Pond.

- Plant floor drains – Floor drain discharges are directed to the Economizer Pond via a combined storm water lift station.

- Coal pile runoff – Runoff from a portion of the coal pile is collected and discharged to the Economizer Pond via a combined storm water lift station.

- Stormwater – Stormwater from industrial use areas are collected and discharged to the Economizer Pond via a combined storm water lift station. Stormwater that collects in the Ash Seal Pond is discharged to the Main Ash Pond on an as-needed emergency basis only.

A portion of the CCR generated at BGS (fly ash) is dry-handled and managed off site through beneficial use, and IPL intends to continue beneficially using CCR when and where it is appropriate. However, after review of the on-site and off-site alternative capacity for disposal of the wet-handled CCR and sluice water or non-CCR wastestreams described above, the conclusion is that there is no current on-site or off-site alternative capacity. New alternative disposal capacity is needed to allow IPL to cease discharges of these wastestreams to the CCR surface impoundments. The development of that alternative disposal capacity requires the closure of the CCR surface impoundments, the elimination or rerouting of coal pile runoff, the installation of significant new infrastructure (e.g., on-site storage, force mains, etc.) to access potential off-site disposal alternatives, or some combination of these needs.

On-site Capacity

All four CCR surface impoundments are subject to the closure requirements in 40 CFR §257.101(a). Additionally, there are no additional on-site impoundments that can be placed into service to provide alternative on-site disposal capacity. No current alternate on-site capacity in the form of tanks is available. Based on the flows described above and on Figure 6, an average of 2.673 MGD and up to 7.86 MGD (approximately 1,850 gallons per minute [gpm] or up to 5,400 gpm) of CCR and non-CCR wastestreams need to be treated. This would require as many as 100 temporary portable weir tanks with a capacity of 50 gpm for a 6-hour residence time (CCG 2020) and an estimated 3 acres of space (minimum) to manage these wastestreams on site. There is not 3 acres of available space within the developed areas of the site and space to the north, south, or west cannot be developed without extensive permitting and impacts to the environment, as described below. This number of tanks also creates a risk of leaks in the interconnected piping, which would be considered an unauthorized bypass by the facility's NPDES permit. For these reasons, the installation of a temporary tank farm is not considered a feasible option at BGS. , which is not feasible due to the number of tanks and space required.

IPL owns land to the south of the current plant (see Figure 7), but those areas are forested wetlands (USFWS 2020). The impacts to the environment, including endangered species, would also be significant based on preliminary reviews of species in the area of BGS (Impact7G 2020). IPL does not own additional land to the west or north of the site that can be used for operations without significant environmental impact and permitting delays due to the presence of wetlands (USFWS 2020) and the 100-year floodplain (Des Moines Co. 2020). The Mississippi River is directly east of the plant, and it is not possible to develop capacity within a major waterway due to the environmental impact and because it would encroach on floodways.

Off-site Capacity

Alternative treatment and disposal of some of these wastestreams using publicly owned treatment works (POTW) might be possible if BGS was located in an existing service area of a local POTW, and it was allowed under current regulations for the facility to accept the wastestream. However, the facility is not located in an existing POTW service area, and there is no existing connection to a POTW that provides conveyance of the wastestreams from BGS. Off-site disposal of these wastestreams at a POTW would require IPL to develop significant new infrastructure, including pumps, interconnected piping, tanks, and loadout equipment for hauling by trucks, or new conveyance infrastructure (a force main and lift station) to send wastewaters off site. Hauling these wastestreams offsite for treatment and disposal is not feasible based on the number of trucks and truckloads required to transport the wastewater (estimated at over 560 truckloads per day on average assuming a 7,500 gallon tanker truck is used to take wastewater to a POTW approximately 5 miles away). This number of truckloads would require a truck to fill and depart BGS every 2 to 3 minutes for 24 hours each day, which is not feasible or safe. The number of trucks required traveling the rural highway and residential streets between BGS and the POTW also presents a safety hazard. Off-site capacity has been evaluated but is not available for the reasons stated above.

CCR wastestreams that are dry handled include fly ash that is collected dry and beneficially used off site. Dry handled wastestreams are not currently managed in the on-site CCR surface impoundments.

Future Capacity

IPL is planning to convert the coal-fired unit (Unit 1) at BGS to be fired with natural gas after the cessation of coal-fired operations by December 31, 2021. Additional discussion of IPL's efforts to develop the necessary alternative disposal capacity for future non-CCR wastestreams is provided below.

Following the conversion of Unit 1 to natural gas, on-site alternatives for disposal of these wastestreams will require the construction of new infrastructure. The space required for this infrastructure is currently occupied by the CCR surface impoundments and requires significant changes to coal pile runoff management. Developing new on-site disposal capacity requires IPL to close at least one of the CCR surface impoundments first.

IPL evaluated numerous options for developing future capacity for non-CCR waste streams after the conversion of BGS to natural gas. Based on that analysis, IPL is developing plans to close the Ash Seal Pond in 2021 by removing the accumulated CCR and sediment from the impoundment. Once the Ash Seal Pond is closed by removal, the area will be prepared for the construction of new wastewater treatment facilities that will manage non-CCR wastestreams following the plant refueling to natural gas. The steps necessary to develop the new facilities include:

- Planning/design for Ash Seal Pond closure such as identification of a suitable onsite disposal location, dewatering plan preparation, and excavation design
- Planning/design for new lined pond to provide TSS treatment, sizing, and rerouting wastewater flows
- Permitting for Ash Seal Pond closure and new wastewater pond construction
- Procurement for closure and new pond construction
- Excavation of the Ash Seal Pond contents
- Site preparation for new pond construction

- Installation of the new lined wastewater pond
- Rerouting of non-CCR wastewater flows to the new wastewater pond
- Commissioning of new wastewater treatment pond

The anticipated schedule for these activities is described further in **Section 3.4.**

3.2 RISK MITIGATION PLAN

To demonstrate that potential risks to human health and the environment from the continued operation of the CCR surface impoundments have been adequately mitigated as required by 40 CFR 257.103(f)(2)(ii), a risk mitigation plan addressing the items in 40 CFR §257.103(f)(2)(v)(B)(*1*) through (*3*) is provided in the sections that follow.

3.2.1 Limiting Future Groundwater Releases

Per 40 CFR §257.103(f)(2)(v)(B)(*1*), the following text provides a discussion of the physical or chemical measures BGS can take to limit future releases to groundwater during continued operation of the CCR surface impoundments.

Lithium and molybdenum have been detected at statistically significant levels (SSL) above the groundwater protection standard (GPS) in samples from more than one downgradient monitoring well at BGS. IPL is working to address these existing groundwater impacts through the Corrective Action process in 40 CFR §257.96-98. All of the potential Corrective Measures identified during the Assessment of Corrective Measures for lithium and molybdenum impacts involve closing the ponds to provide source control along with additional controls to ensure exposure pathways are adequately addressed. IPL is currently designing a remedy that is consistent with pond closures that must be completed by October 17, 2023. Additional detail on the groundwater impacts and the corrective action process are provided in **Section 3.3.2** through **3.3.6.**

No specific, immediate physical or chemical measures were identified that BGS can implement to limit the existing groundwater impacts during the limited remaining operational life of the impoundments. Immediate retirement of BGS is not an option because the facility must remain available to meet current capacity requirements for electric grid reliability. Operationally, all of the CCR surface impoundments are currently needed to meet the limits established in the National Pollutant Discharge Elimination System (NPDES) permit for BGS. In addition, any changes to process chemistry must pass an antidegradation analysis required by the Clean Water Act and be approved through an amendment to the facility's NPDES permit. Both of these considerations limit flexibility during the remaining operational life of the impoundments between April 11, 2021 and December 31, 2021.

However, during the remaining active life of the ponds, IPL is actively pursuing the permanent end to wastewater discharges. Ending the discharge of wastewater, including low volume wastewaters, to the ponds is expected to accelerate groundwater quality improvements. IPL is currently preparing for future treatment/disposal capacity for wastestreams that will remain after Unit 1 is refueled to natural gas. IPL is designing new wastewater treatment and working to obtain the necessary approvals to implement the new treatment. IPL is also currently installing an alternate water supply to reduce the need to treat Mississippi River water and discharge treatment residuals as low volume waste water. The new water supply is expected to substantially reduce the amount of low volume waste water produced by the facility and improve the quality of the low volume waste water.

3.2.2 Mitigating Groundwater Exposures

Per 40 CFR §257.103(f)(2)(iv)(B)(2), the following sections provide a discussion of the CCR surface impoundment's groundwater monitoring data and any found exceedances; the delineation of the plume (if necessary based on the groundwater monitoring data); identification of any nearby receptors that might be exposed to current or future groundwater contamination; and how such exposures could be promptly mitigated.

Groundwater Monitoring and Found Exceedances

IPL uses a multi-unit groundwater monitoring system to monitor groundwater quality in the area of the four CCR surface impoundments at BGS. The groundwater monitoring system includes the following:

- Two shallow background monitoring wells (MW-310 and MW-311) screened in the uppermost aquifer, an alluvial sand aquifer underlying surficial clay and silt.

- Eleven shallow downgradient monitoring wells (MW 301, MW-302, MW-303, MW304, MW-305, MW-306, MW-307, MW-308, MW-309, MW-312, and MW-313) screened in the uppermost aquifer

- Four deeper monitoring wells (MW-302A, MW-307A, MW-310A, and MW-313A) screened deeper in the alluvial sand aquifer or underlying bedrock

Groundwater monitoring well locations are shown on **Figure 2**. The CCR surface impoundment monitoring system at BGS is discussed further in **Section 3.2.2**.

The CCR surface impoundments at BGS are currently in Corrective Action. Based on groundwater monitoring completed to date, lithium and molybdenum have been detected at statistically significant concentrations above the GPS in the following monitoring wells:

- Lithium – MW-302, MW-303, MW-304, MW-306, MW-307, MW-308, and MW-313
- Molybdenum – MW-302, MW-307, MW-308, MW-312, and MW-313

Additional details regarding the groundwater monitoring results for BGS are provided in **Section 3.3.3** and the attached tables. Pursuant to 40 CFR §257.96(b), groundwater continues to be monitored in accordance with the assessment monitoring program while in Corrective Action.

Plume Delineation and Potential Receptors

An Assessment of Corrective Measures (ACM) for the lithium and molybdenum impacts at BGS was completed in September 2019 (see **Appendix C1**), and the remedy selection process was initiated. An addendum to the ACM (Addendum No. 1) was issued in November 2020 to provide an update of available site data obtained since the ACM was completed and to evaluate additional Corrective Measures. A copy of Addendum No, 1 is provided in **Appendix C2**.

Part of the remedy selection process has included the installation of additional monitoring wells to refine information presented in the ACM regarding the nature and extent of groundwater impacts. As discussed in the recent September 2020 semiannual remedy selection report and the ACM addendum, four deeper monitoring wells were recently installed to gather additional information on the horizontal and vertical extents of groundwater impacts (SCS, 2020a and 2020b). Based on the groundwater monitoring data obtained to date, IPL has determined that shallow groundwater in the vicinity of BGS flows east toward the Mississippi River, which indicates that no impacts would extend west of the ponds in the upgradient direction. This is supported by monitoring data from upgradient wells MW-309 and MW-310, where lithium and molybdenum have not been detected above the GPS.

The northern horizontal limits of lithium and molybdenum impacts are defined by MW-305, where no groundwater samples have contained concentrations of these two metals above the GPS. The eastern and southern limits of impacts remain undefined due to the proximity of the Mississippi River to the east of the site and inaccessible wetlands to the south. IPL owns the adjacent property to the south, which extends roughly 4,000 feet further down the river. IPL is continuing to evaluate information from the recently installed wells to determine what, if any, impacts extend to the east or south. Additional details regarding the groundwater monitoring data obtained at BGS, the ACM, and remedy selection process are provided in **Sections 3.3.3** through **3.3.6**.

The Mississippi River, more specifically the human, plant, and animal users of the river, is the only potential nearby receptor identified in the September 2019 ACM report. The pathway to exposure of the Mississippi River as a receptor is the interaction of lithium- and molybdenum-impacted groundwater with the river. Preliminary analysis suggests that groundwater discharge to the river is small relative to the volume of flow in the river. No downgradient or sidegradient water supply wells were identified in the search conducted as part of the ACM, and the on-site water supply well is not used to provide potable water to BGS. Additional detail regarding the identification of potential receptors and exposure pathways is provided in the ACM and Addendum No. 1 (see **Appendix C1** and **C2**).

Activities since the ACM was completed are summarized in Addendum No. 1 and have included the delineation of lithium and molybdenum impacts in groundwater and the evaluation of the pathways of exposure. Additional groundwater monitoring wells have recently been installed and groundwater samples collected. Based on the latest available groundwater data, SCS completed a preliminary evaluation of the groundwater to surface water interactions of lithium and molybdenum in groundwater. The preliminary evaluation completed by SCS included:

- Review of USEPA and state surface water standards for lithium and molybdenum.
- Literature review for toxicity of lithium and molybdenum.
- Review of application materials and studies conducted by IPL for the renewal of the NPDES permit for BGS.

Based on evaluations to date, the lithium and molybdenum impacts to groundwater at BGS are unlikely to impact the river.

Mitigation Options

The corrective measures identified in the September 2019 ACM and Addendum No. 1 that were deemed viable all anticipated the cessation of coal-fired operations and closure of the CCR surface impoundments at BGS. The review of potential receptors, pathways to exposure, and risks associated with the groundwater impacts at BGS completed with the September 2019 ACM indicated that the timeline for the cessation of coal-fired operation of Unit 1, receipt of CCR and non-CCR wastestreams by the CCR surface impoundments, and final closure by various methods combined with monitored natural attenuation (MNA) was a suitable approach for the site. Additional groundwater data and the ongoing evaluation of the MNA mechanisms active at BGS and the attenuation capacity of the site are discussed in Addendum No. 1 (see **Appendix C2**). Additional corrective measure alternatives that include new source control and containment alternatives have been evaluated in Addendum No. 1, and a final closure approach is yet to be selected.

Should the concentrations of molybdenum and lithium observed in groundwater at BGS increase significantly or new constituents be identified at concentrations greater than their respective GPS, IPL will evaluate the nature and extent of the emergent concern and, as needed, will deploy additional groundwater plume containment options. Additional mitigation measures may include plume containment options such as:

- In-situ permeable reactive barriers
- Slurry wall(s)
- Groundwater pump and treat

These groundwater plume containment options are described further in Section 3.2.3. Other mitigation scenarios may be evaluated by IPL as appropriate based on the specifics of the identified exposure pathway. The efficacy of any option will require additional evaluation prior to implementation.

3.2.3 Containing Groundwater Impacts

Per 40 CFR §257.103(f)(2)(iv)(B)(*3*) the following text discusses options for expediting and maintaining the containment of any contaminant plume that is either present or identified during continued operation of the CCR surface impoundments at BGS.

Based on the current groundwater monitoring data and evaluation of receptors and potential exposures to the lithium and molybdenum, IPL is designing a remedy, pursuant to 40 CFR §257.97, that is intended to control the source of impacts and monitor changes to ensure that exposure pathways do not emerge. Source control is mostly likely achieved through closure of the CCR surface impoundments under a final cover system that meets the performance standards in 40 CFR §257.102. Current design considerations include consolidation of the material on site to reduce the size of potential sources and minimizing future potential for interaction with groundwater. Prior to pond closure, IPL will implement interim measures intended to expedite containment of the plume. Specifically, this includes the installation of an alternative water source that will eliminate low volume waste water produced from the treatment of river water. Reducing the volume of waste water discharged to the ponds will decrease the potential to mobilize constituents and expedite plume containment.

IPL is also evaluating the capacity of the site and the local hydrogeology to naturally contain and attenuate the observed impacts. MNA may also be used to verify improvements in groundwater quality. The proximity of the Mississippi River limits, but does not necessarily preclude, the potential for natural attenuation within the confined aquifer or within the sediments that likely cover the base of the river. When groundwater flow is to the south there are potentially several thousand feet of potential flow in which natural attenuation could mitigate constituent concentrations before discharge to the river.

In the event that significant changes in groundwater quality are observed as described in Section 3.2.2, IPL will evaluate additional containment measures. IPL has evaluated these containment measures to address the current lithium and molybdenum impacts to groundwater at BGS, and the measures are discussed in the ACM addendum (see Appendix C2). The additional containment measures are also described below.

In-situ Permeable Reactive Barriers (PRB)

PRBs are a well-established technology that have been applied at industrial and mining sites to mitigate the migration of a variety of trace and radioactive elements in groundwater. Several reagents, both chemical and biological, can be placed in the PRB to tailor the sequestration to the specific elements of concern. Laboratory treatability studies are needed to identify the appropriate reagent(s) and assess physical design parameters. Reagent emplacement could be by either physical emplacement (excavation) or injection into the site soil. Long-term performance of the PRB would be evaluated with on-going groundwater monitoring. A single PRB or several shorter PRBs can be installed depending on the contaminants and plume to be contained.

Slurry Wall

A slurry wall, typically constructed by placing a soil, bentonite, water, and possibly cement mixture placed in a trench, will act as a physical barrier to the migration of contaminated groundwater or to divert clean groundwater from the source of contamination. At BGS, slurry walls could be strategically installed to impede contaminated groundwater migration. The effectiveness of slurry walls at BGS may be impacted by the lack of a low permeable geologic unit to provide a “key” for the bottom of the wall. Instead, slurry walls at BGS may be installed as “hanging” walls, which may need to be combined with another technology to provide the containment necessary. The installation will depend on the contaminants and plume being contained (Federal Remediation Technologies Roundtable [FRTR], Version 4.0).

Groundwater Pump and Treat

Groundwater pumping with ex situ treatment is a proven method for containing groundwater contaminant plumes (FRTR, Groundwater Pump, and Treat). The technology involved is relatively simple and can be deployed rapidly in the event of a significant new release. Groundwater treatment will depend on the constituents in the contaminant plume. The type of specific treatment for CCR-related constituents will be considered at the time when it is determined that a treatment technology needs to be evaluated. Readily available treatment technologies could be considered for many of the constituents (e.g., ion exchange treatment technology), but the evaluation of the best individual treatment technology will depend on the following:

1. Groundwater contaminant and that constituent’s concentration
2. Competing ionic constituent concentration(s)
3. Design flow rate of the groundwater to be treated
4. Required post-treatment discharge concentrations
5. Technology feasibility and operation

Because the groundwater pump and treatment approach can be complex and require significant long-term operation and maintenance support, this approach to plume containment will likely be most applicable to new releases that pose a significant risk to groundwater receptors.

These preliminary groundwater plume containment strategies may be pursued in response to changes to current releases or in the event of a new release. They may also be employed along with source control methods, such as closure of the CCR surface impoundments and others described in the September 2019 ACM and Addendum No. 1, should MNA be determined ineffective. The groundwater conditions will continue to be monitored, and in the event the data indicate that an exposure pathway is complete, IPL will advance appropriate containment measures.

3.3 COMPLIANCE WITH CCR REQUIREMENTS

Per 40 CFR §257.103(f)(2)(v)(C)(*1*) through (*8*), **Section 3.3** and related subsections are provided along with the supporting tables, figures, and appendices to support the demonstration and owner/operator certification of compliance with the CCR Rule.

There are four existing CCR surface impoundments at BGS:

- BGS Ash Seal Pond
- BGS Main Ash Pond
- BGS Economizer Ash Pond
- BGS Upper Ash Pond

All four of these impoundments are the subject of this demonstration, and there are no additional CCR units at this facility. As described in detail below, the facility is in compliance with all other requirements of the CCR Rule, including the requirement to conduct any necessary corrective action.

3.3.1 Certification by Owner/Operator

Per 40 CFR §257.103(f)(2)(v)(C)(*1*), a certification statement signed by a responsible official with IPL, the operator of BGS, that the facility is in compliance with all of the requirements of 40 CFR §257, Subpart D is included in **Appendix A.**

3.3.2 Groundwater Monitoring System

Per 40 CFR §257.103(f)(2)(v)(C)(*2*), the following text and supporting figures and appendices provide a visual representation of hydrogeologic information at and around the CCR unit(s) that supports the design, construction, and installation of the groundwater monitoring system.

The original groundwater monitoring system established in accordance with the CCR Rule consists of two upgradient (background) monitoring wells and nine downgradient monitoring wells. The background wells are MW-310 and MW-311. The nine initial downgradient wells are MW-301, MW-302, MW-303, MW304, MW-305, MW-306, MW-307, MW-308, and MW-309. These wells were installed between December 2015 and March 2016. Two additional downgradient monitoring wells, MW-312 and MW-313, were installed in May 2019 in accordance with the assessment monitoring requirements of 40 CFR §257.95(g)(1). Monitoring wells MW-301 through MW-313 are installed in the upper portion of the alluvial aquifer, and the well depths range from approximately 19 to 34 feet below ground surface. Four deeper monitoring wells (MW-302A, MW-307A, MW-310A, and MW-313A) were installed in June and July 2020 to provide information on vertical groundwater flow and the vertical distribution of target groundwater quality parameters. Each of the new wells was installed adjacent to a pre-existing well (MW-302, MW-307, MW-310, and MW-313), and is 30 feet deeper than the adjacent well.

A map of groundwater monitoring well locations in relation to the CCR units is included as **Figure 2**. Well construction diagrams and drilling logs are included in **Appendix B.**

Groundwater at the site generally flows east toward the Mississippi River. A seasonal variation in the groundwater flow direction near the river from east to southeast is evident in **Figures 3** and **4.**

3.3.3 Groundwater Monitoring Results

Per 40 CFR §257.103(f)(2)(v)(C)(3), the following text, supporting tables, and appendices provide constituent concentrations at each groundwater monitoring well monitored during each sampling event.

Groundwater monitoring samples have been collected and analyzed in accordance with the Sampling and Analysis Plan (SAP) for BGS (see **Appendix B4**). Statistical analysis of groundwater monitoring results at BGS is conducted as described in Appendix C of the SAP, and is performed in general accordance with the USEPA's Unified Guidance for Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities dated March 2009 (Unified Guidance) (EPA 530-R-09-007, March 2009) and generally accepted procedures.

Background Sampling and Detection Monitoring Results

Background sampling began in April 2016 and concluded in August 2017. Eight groundwater samples were collected from each CCR monitoring well for the establishment of background. Background samples were analyzed for both Appendix III and Appendix IV constituents. A summary of all groundwater monitoring results collected at each monitoring well is provided in table form in **Appendix B.** A copy of the most recent Annual Groundwater Quality Report is also provided in **Appendix B.**

Following completion of eight background groundwater monitoring events, compliance monitoring was initiated at BGS. The complete results for all compliance sampling events are summarized in **Table 1.**

The statistical evaluation of the October 2017 detection monitoring results, completed in January 2018, identified statistically significant increases (SSIs) in detection monitoring constituents at the downgradient wells. SSIs were identified for boron, calcium, fluoride, field pH, and sulfate at one or more wells based on the October 2017 detection monitoring event (**Table 1**). Assessment monitoring began in April 2018, in accordance with §257.95(b).

Assessment Monitoring Results and Assessment of Corrective Measures

Following the initiation of assessment monitoring, the detection of lithium and molybdenum at SSL above the GPS in samples from more than one downgradient monitoring well (**Table 1**).

The (USEPA's) Unified Guidance recommends the use of confidence intervals for comparison of assessment monitoring data to fixed GPS values. Specifically, the suggested approach for comparing assessment groundwater monitoring data to GPS values based on long-term chronic health risk, such as drinking water Maximum Contaminant Levels (MCLs), is to compare the lower confidence limit (LCL) around the arithmetic mean with the fixed GPS. Although a confidence interval approach is recommended, a minimum of four samples are required for this approach.

Following the collection of four rounds of groundwater data, The LCLs were determined with the lithium (**Table 2**) and molybdenum (**Table 3**). The LCL comparisons confirmed that following wells and parameters exceeded the GPS as SSIs:

Assessment Monitoring Appendix IV Parameters	Location of GPS Exceedance(s)	Historic Range of Detections at Wells Exceeding GPS	Groundwater Protection Standards (GPS)
Lithium (µg/L)	MW-302, MW-303, MW-307, MW-308	34.3 – 82.4	40
Molybdenum (µg/L)	MW-302, MW-307, MW-308	47.4 - 159	100

µg/L = micrograms per liter
Note: Historic range includes results from assessment monitoring beginning in April 2020.

The ACM was initiated in February 2019 and was completed in September 2019. Addendum No. 1 to the ACM was completed in November 2020. The ACM and Addendum No. 1 are discussed further in **Section 3.3.5**.

The Selection of Remedy Process

The Selection of Remedy process was initiated following the completion of the September 2019 ACM. As mentioned in **Section 3.3.2.**, additional monitoring wells were installed to expand the network in May 2019. In June and July 2020 four deeper wells were installed.

The concentration of molybdenum and lithium in groundwater samples from MW-312 and MW-313 were greater than the GPS in the June 2019, October 2019, and June 2020 sampling events; however, four rounds of analytical results are needed to calculate the LCL for each parameter. Following additional groundwater sampling in October 2020, LCLs for molybdenum and lithium at MW-312 and MW-313 will be calculated for comparison to the GPS for each parameter. Molybdenum concentrations in groundwater samples collected from piezometers, MW-302A, MW-307A, and MW-313A in September 2020, were greater than the GPS.

To evaluate whether lithium and molybdenum are present in groundwater at the newly installed wells at statistically significant levels above the GPS, the LCL for the mean will be calculated once four results are available (minimum for calculation - see **Table 2** and **3**).

3.3.4 Hydrogeology

Per 40 CFR §257.103(f)(2)(v)(C)(*4*), the following text, supporting figures, and appendices provide a description of site hydrogeology including stratigraphic cross-sections.

The uppermost geologic formation beneath BGS that meets the definition of the "uppermost aquifer," as defined under 40 CFR 257.53, is the surficial alluvial aquifer. The alluvial aquifer comprises Mississippi River valley clay, silt, sand, and sand and gravel deposits. The alluvial aquifer is underlain by Devonian-Mississippian limestone bedrock, which is identified as a regional aquiclude.

A geologic cross section was prepared with background monitoring well MW-310 and downgradient monitoring wells MW-306 and MW-312. The cross section line runs through the lower southwest section of the BGS Upper Ash Pond, BGS Economizer Ash Pond, and the coal pile. The cross section location is provided on **Figure 2**, and the geologic cross section is provided on **Figure 5.** Unconsolidated geologic material and groundwater levels estimated using water levels measured at site monitoring wells are identified on the cross section.

3.3.5 Assessment of Corrective Measures

Per 40 CFR §257.103(f)(2)(v)(C)(5) this section provides a brief summary and reference to the ACM and subsequent addendum completed for the CCR surface impoundments at BGS as required by 40 CFR 257.96. A copy of the completed ACM and Addendum No. 1 are provided in **Appendix C.**

The corrective measures presented in that report are intended to bring the levels of lithium and molybdenum in groundwater below USEPA standards. In addition to stopping the discharge of CCR and non-CCR wastestreams to the ponds, these corrective measures include:

- Cap CCR in Place with MNA
- Consolidate CCR and Cap with MNA
- Excavate and Dispose CCR on Site with MNA
- Excavate and Dispose CCR in Off-site Landfill with MNA
- Consolidate and Cap with Chemical Amendment (added with Addendum No. 1)
- Consolidate and Cap with Groundwater Collection (added with Addendum No. 1)
- Consolidate and Cap with Barrier Wall (added with Addendum No. 1)

IPL has also presented a “No Action” alternative for comparison purposes only.

The September 2019 ACM includes a preliminary evaluation of five initial options using factors identified in the Rule. Based on what is currently known, the groundwater impacts at BGS are limited, but are not completely understood. IPL will continue to work on understanding groundwater impacts at BGS, and will use this information to select one of the Corrective Measures identified above.

Since the September 12, 2019 ACM report, IPL has continued to provide semiannual updates on its progress in evaluating Corrective Measures to address the groundwater impacts at BGS. The most recent semiannual update was provided in September 2020. Based on information obtained to date, Addendum No. 1 to the ACM was prepared to summarize the current understanding of the groundwater impacts at BGS, identify additional potential corrective measure alternatives, and revisit the evaluation of corrective measure alternatives in accordance with 40 CFR 257.96.

IPL held a public meeting on October 14, 2020, to discuss the contents of the September 2019 ACM, as required by 40 CFR §257.96(e). An additional public meeting will be held with interested and affected parties to discuss the results of Addendum No. 1 at least 30 days before a remedy is selected.

3.3.6 Selection of Remedy

Per 40 CFR §257.103(f)(2)(v)(C)(6) this section provides a brief summary of progress on remedy selection and design required by 40 CFR §257.97(a).

IPL has advanced the Selection of Remedy process in accordance with 40 CFR §257.97(a). Semi-annual updates have been provided in March 2020 and September 2020 since the issuance of the September 12, 2019 ACM report. Copies of the semiannual updates are included in **Appendix D.**

The ACM was updated with Addendum No. 1 in November 2020. Additional groundwater data collection and analysis is still needed for the evaluation of the MNA option. Updates to the assessment, and development of the quantitative evaluation system discussed in the ACM and

Addendum No. 1, will be completed in the future based on updates to the conceptual site model, delineation of the nature and extent of impacts, and collection of additional data relevant to remedy selection.

Planned activities related to the remedy selection process are described in Addendum No. 1 (see **Appendix C2**) and include the following:

- Collect groundwater samples at the four new piezometers.
- Continue semiannual assessment monitoring for the existing monitoring well network and new monitoring wells.
- Evaluate MNA feasibility, including additional evaluation of groundwater flow and groundwater quality.
- Update conceptual site model based on findings of nature and extent investigation.
- Evaluate potential interactions between endangered resources and remedies.
- Design pond closures to reduce the size of potential sources and minimize future potential for interaction with groundwater.
- Evaluate permits and approvals required for ash pond closure and construction of new wastewater treatment.
- Obtain an alternate water supply to reduce the need to treat river water and discharge treatment residuals as low volume waste water.
- Reroute wastewater to facilitate pond closure.
- Continue evaluation of remedial options.

IPL is pursuing these remedy selection activities to finalize the selection of remedy process and complete the closure of the ash ponds at BGS by October 17, 2023.

3.3.7 Structural Stability Assessment

Per 40 CFR §257.103(f)(2)(v)(C)(7) this section provides a brief summary of the Structural Stability Assessment completed in August 2016 (**Appendix E**). The assessment was performed in accordance with the 40 CFR §257.73(d). The assessment indicates that the CCR units (Ash Seal Pond, Main Ash Pond, Economizer Pond, and Upper Ash Pond) have been designed, constructed, operated, and maintained to meet the CCR Rule requirements. A summary of the Structural Stability Assessment is provided in table form along with a copy of the report in **Appendix E**.

3.3.8 Safety Factor Assessment

Per 40 CFR §257.103(f)(2)(v)(C)(8) this section provides a brief summary of the Safety Factor Assessment was completed in August 2016 (**Appendix F**). The assessment was performed in accordance with 40 CFR §257.73(e). The assessment indicates that the CCR units (Ash Seal Pond, Main Ash Pond, Economizer Pond, and Upper Ash Pond) have acceptable minimum safety factors for the critical cross sections of the embankments under the loading conditions analyzed. A summary of the Safety Factor Assessment is provided in table form along with a copy of the report in **Appendix F**.

3.4 SCHEDULE

Per 40 CFR §257.103(f)(2)(v)(D) this section provides a narrative that specifies and justifies the day by which IPL intends to cease receipt of waste into the CCR surface impoundments at BGS in order to meet the closure deadline of October 17, 2023. Also provided in **Appendix G** is an updated closure plan that reflects the proposed schedule as required by 40 CFR §257.102(b).

IPL is currently evaluating options for non-CCR wastewater management during post-coal fired operations at BGS. Beginning in late-2018, IPL began evaluating options for managing low-volume wastewater from BGS operations without the CCR surface impoundments, and engaged a consulting engineer to study, select, and design treatment options for low-volume wastewater at BGS. IPL completed engineering evaluations early in 2020 and completed additional wastewater sampling to confirm the selected approach. The confirmation sampling was delayed by Mississippi River flooding, plant downtime, and the COVID-19 pandemic. Unexpected high total suspended solids (TSS) results obtained during the confirmation sampling event indicated additional evaluations were needed. IPL is currently working to implement a strategy for non-CCR wastewater management, which requires development of a new lined wastewater pond within the footprint of the existing Ash Seal Pond. Design and permitting for the new treatment pond is underway, which is critical to the overall timing of the CCR surface impoundment closures.

Another critical schedule element is the remedy selection process. As discussed in **Section 3.3.6** and the most recent semiannual update report provided in **Appendix D**, the installation of new, deeper monitoring wells was delayed by floodplain permitting and the COVID-19 pandemic. The additional well installations are complete and one of two critical rounds of groundwater samples have been collected (as of this draft). The second round of samples will be collected in early October, so results may still be under evaluation at the time of USEPA's review. However, with this additional data, the remedy selection process can proceed at a more accelerated pace.

The schedule developed for CCR surface impoundment closure by October 17, 2023, assumes a hybrid approach will be used and requires the excavation and consolidation of an estimated 500,000 cubic yards (cy) of CCR and sediment from the four CCR surface impoundments with the remaining CCR closed in place. Based on the volume of material to be managed during the closure and preliminary estimates of capped areas, core closure construction tasks including CCR consolidation and capping will be completed in approximately 10 to 12 months with 2 to 4 months allowed for site preparation, minor demolition, storm water infrastructure construction, and restoration. We assume no construction will occur during the winter months (approximately December 1 through March 31 each year) due to the technical difficulties associated with placing and compacting frozen materials, as wells as additional safety concerns stemming from work in cold weather.

IPL is committed to completing the closure of the CCR surface impoundments by October 17, 2023, by pursuing the following schedule:

- October 2020 – Finalize an approach for managing low-volume wastewater following the end of coal-fired operations.
- November 2020 – Finalize Addendum No. 1 to the ACM.
- December 2020 – Finalize planning and design of Ash Seal Pond closure.
- February 2021 – Finalize planning and design of new non-CCR wastewater treatment facility.
- April 2021 – Complete permitting and procurement for Ash Seal Pond closure construction.
- May 2021 – Initiate Ash Seal Pond closure by removal.
- June 2021 – Complete permitting and procurement for new wastewater treatment construction.
- July 2021 – Begin site preparation and new wastewater facility construction
- December 2021 – Complete construction and commission new non-CCR wastewater treatment facility.

- December 31, 2021 – End coal-fired operation of Unit 1. Stop receiving CCR and non-CCR wastestreams at CCR surface impoundments. BGS will continue to operate using natural gas as fuel.
- April 2022 – Start remaining surface impoundment closure construction.
- June 2022 – Complete decommissioning of select coal handling equipment and initiate coal pile remediation/closure.
- Complete CCR surface impoundment closure – October 17, 2023.

Additional schedule detail is provided in **Appendix G**.

4.0 REFERENCES

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Tables

Table 1. Groundwater Analytical Results Summary - Compliance Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25220066.00

Parameter Name	UPL Method	UPL	GPS	Background Wells														
				MW-310							MW-310A^^	MW-311						
				10/16/2017	5/9/2018	8/14/2018	10/10/2018	4/4/2019	10/11/2019	6/2/2020	9/9/2020	10/16/2017	5/9/2018	8/14/2018	10/10/2018	4/4/2019	10/11/2019	6/2/2020
Appendix III																		
Boron, ug/L	NP	2,950		305	217	256	268	560	380	500	2,200	2,810	2,200	2,580	2,820	1,800	2,800	2,500
Calcium, mg/L	P	210		105	104	102	107	120	120	130	150	145	173	156	130	200	150	190
Chloride, mg/L	P	209		38.3	24.4	33.8	67.1	88	59	87	18	50.9	79.9	69.9	54	110	65	120
Fluoride, mg/L	P	0.427		0.39	0.33	0.39	0.4	0.55	0.34 J	0.65	0.27 J	0.36	0.31	0.36	0.35	0.41 J	0.37 J	0.64
Field pH, Std. Units	P	8.17		7.92	7.46	7.44	7.20	7.84	6.95	7.30	7.33	8.27	7.26	7.33	7.49	7.64	7.07	7.10
Sulfate, mg/L	P	457		35.1	28.8	27.2	37.9	21	51	100	100	119	176	144	127	230	130	220
Total Dissolved Solids, mg/L	P	1,113		445	462	472	512	600	410	590	570	615	864	777	678	980	590	950
Appendix IV		**UPL**	**GPS**															
Antimony, ug/L	P*	0.17	6	NA	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58	1.1	NA	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58
Arsenic, ug/L**	P	114.9	114.9	NA	57.8	56.2	62.1	65	61	55	15	NA	14.0	15.7	15.2	19	18	19
Barium, ug/L	P	1,147	2,000	NA	403	398	450	560	500	550	290	NA	256	239	214	280	210	300
Beryllium, ug/L	NP*	0.036	4	NA	<0.012	<0.12	<0.089	<0.27	<0.27	<0.27	2.3	NA	<0.023 D3	<0.12	<0.089	<0.27	<0.27	<0.27
Cadmium, ug/L	NP*	0.025	5	NA	<0.018	<0.070	<0.033	<0.077	<0.039	<0.039	0.69	NA	<0.018	<0.070	<0.033	<0.077	<0.039	<0.039
Chromium, ug/L	P*	0.090	100	NA	0.16 J,B	<0.19	0.082 J	<0.98	<0.98	<1.1	5.4	NA	0.20 J,B	0.22 J	0.78 J	<0.98	<0.98	<1.1
Cobalt, ug/L	P	3.87	6	NA	1.2	1.4	1.4	1.9	1.9	2.3	28	NA	0.30 J	0.37 J	0.57 J	0.45 J	0.27 J	0.81
Fluoride, mg/L	P	0.427	4	NA	0.33	0.39	0.4	0.55	0.34 J	0.65	0.27 J	NA	0.31	0.36	0.35	0.41 J	0.37 J	0.64
Lead, ug/L	NP*	0.64	15	NA	0.044 J	<0.12	<0.13	<0.27	<0.27	<0.27	20	NA	0.043 J	0.13 J	0.48 J,B	0.37 J	<0.27	1.1
Lithium, ug/L	NP*	7.7	40	NA	<4.6	5.3 J	<4.6	<2.7	<2.7	<2.3	32	NA	<4.6	<4.6	<4.6	<2.7	<2.7	<2.3
Mercury, ug/L	DQ	DQ	2	NA	<0.090	NA	<0.090	<0.10	NA	<0.10	<0.10	NA	<0.090	NA	<0.090	<0.10	NA	0.13 J
Molybdenum, ug/L	NP	14.7	100	NA	4.2	4	4.6	5.2	6.0	5.8	19	NA	11.6	13.9	16.3	8.5	15	11
Selenium, ug/L	P*	0.28	50	NA	0.14 J	<0.16	0.19 J	<1.0	<1.0	<1.0	1.5 J	NA	0.17 J	0.18 J	0.23 J	<1.0	<1.0	<1.0
Thallium, ug/L	NP*	0.35	2	NA	<0.036	NA	<0.099	<0.27	NA	<0.26	<0.26	NA	<0.036	NA	<0.099	<0.27	NA	<0.26
Radium 226/228 Combined, pCi/L	P	3.36	5	NA	0.755	1.55	2.56	1.19	0.490	0.844	pending	NA	0.987	0.969	0.819	0.815	0.599	0.802

4.4	Blue highlighted cell indicates the compliance well result exceeds the UPL (background) and the LOQ.
30.8	Yellow highlighted cell indicates the compliance well result exceeds the GPS.
17	Yellow highlighted cell with bold text indicates the compliance well result exceeds the GPS and the result was determined to be statistically significant(1).

Notes: See page 9

Table 1. Groundwater Analytical Results Summary - Compliance Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25220066.00

				Compliance Wells																
Parameter Name	**UPL Method**	**UPL**	**GPS**	**MW-301**								**MW-302**								**MW-302A**
				10/16/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020	10/17/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020	9/9/2020
Appendix III																				
Boron, ug/L	NP	2,950		9,900 M1	9,140	12,800	8,040	NA	12,000	8,100	10,000	10,000	10,200	10,000	10,400	NA	12,000	11,000	13,000	11000
Calcium, mg/L	P	210		140 M1	85.3	174	103	NA	150	130	140	231	231	210	219	NA	220	220	210	120
Chloride, mg/L	P	209		22.0	22.7	21.7	21.5	NA	21	20	22	16.4	14.1	14.7	13.5	NA	13	11	12	27
Fluoride, mg/L	P	0.427		0.27	0.36	0.52	0.26	NA	0.77	<0.23	0.26 J	0.11 J	0.11 J	<0.063	<0.19	NA	0.37 J	<0.23	<0.23	<0.23
Field pH, Std. Units	P	8.17		7.58	7.4	7.91	7.34	6.38	7.53	6.85	6.99	8.72	8.19	9.32	7.89	6.94	8.70	7.49	7.88	7.31
Sulfate, mg/L	P	457		454	188	187	358	NA	190	390	250	541	553	542	658	NA	510	510	490	340
Total Dissolved Solids, mg/L	P	1,113		780	568	960	656	NA	890	690	910	951	1,080	1,000	1,030	NA	1,000	960	1,000	730
Appendix IV		**UPL**	**GPS**																	
Antimony, ug/L	P*	0.17	6	NA	<0.026	<0.15	0.080 J	NA	<0.53	<0.53	<0.58	NA	<0.026	<0.15	0.082 J	NA	<0.53	<0.53	<0.58	<0.51
Arsenic, ug/L**	P	114.9	114.9	NA	34.9	40.1	37.7	NA	42	40	46	NA	56.2	49.6	76.4	NA	53	73	110	2.9
Barium, ug/L	P	1,147	2,000	NA	198	420	276	NA	380	320	330	NA	363	340	180	NA	320	260	340	270
Beryllium, ug/L	NP*	0.036	4	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27	<0.27
Cadmium, ug/L	NP*	0.025	5	NA	0.040 J	<0.070	<0.033	NA	<0.077	<0.039	<0.039	NA	0.037 J	<0.070	0.040 J	NA	<0.077	<0.039	0.045 J	<0.049
Chromium, ug/L	P*	0.090	100	NA	0.25 J, B	0.36 J	0.12 J	NA	<0.98	<0.98	<1.1	NA	0.22 J, B	0.33 J	0.097 J	NA	<0.98	<0.98	<1.1	<1.1
Cobalt, ug/L	P	3.87	6	NA	0.15 J	0.45 J	0.10 J	NA	0.44 J	0.18 J	0.31 J	NA	0.19 J	0.15 J	0.18 J	NA	0.19 J	0.23 J	0.21 J	0.12 J
Fluoride, mg/L	P	0.427	4	NA	0.36	0.52	0.26	NA	0.77	<0.23	0.26 J	NA	0.11 J	<0.063	<0.19	NA	0.37 J	<0.23	<0.23	<0.23
Lead, ug/L	NP*	0.64	15	NA	0.17 J	0.13 J	<0.13	NA	<0.27	<0.27	<0.27	NA	0.17 J	<0.12	<0.13	NA	0.58	<0.27	<0.27	0.11 J
Lithium, ug/L	NP*	7.7	40	NA	17.8	18.9	24.5	NA	13	26	16	NA	**65.4**	**61.4**	**57.8**	**59.9**	**56**	**57**	**55**	11
Mercury, ug/L	DQ	DQ	2	NA	<0.090	NA	<0.090	NA	<0.10	NA	<0.10	NA	<0.090	NA	<0.090	NA	<0.10	NA	<0.10	<0.10
Molybdenum, ug/L	NP	14.7	100	NA	113	81.7	120	62.7	77	130	110	NA	**118**	**121**	**122**	**123**	**100**	**100**	**140**	**120**
Selenium, ug/L	P*	0.28	50	NA	0.25 J	0.28 J	0.13 J	NA	<1.0	<1.0	<1.0	NA	0.25 J	0.22 J	0.23 J	NA	<1.0	<1.0	<1.0	<1.0
Thallium, ug/L	NP*	0.35	2	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26	<0.26
Radium 226/228 Combined, pCI/L	P	3.36	5	NA	0.712	1.15	1.50	NA	1.15	1.03	0.928	NA	1.51	1.53	2.15	NA	0.872	0.644	0.626	pending

4.4	Blue highlighted cell indicates the compliance well result exceeds the UPL (background) and the LOQ.
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Notes: See page 9

Table 1. Groundwater Analytical Results Summary - Compliance Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25220066.00

Parameter Name	UPL Method	UPL	GPS	Compliance Wells															
				MW-303								MW-304							
				10/17/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020	10/17/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020
Appendix III																			
Boron, ug/L	NP	2,950		25,400	22,900	24,500	24,500	NA	22,000	21,000	23,000	5,580	5,140	5,440	6,180	NA	6,300	5,100	6,400
Calcium, mg/L	P	210		84.5	87.0	85.9	87.8	NA	86	91	120	103	107	102	88.5	NA	72	140	150
Chloride, mg/L	P	209		15.3	15.1	15.7	16.3	NA	15	16	18	46.5	58.1	25.9	50.3	NA	39	25	21
Fluoride, mg/L	P	0.427		0.25	0.22	0.44	0.27	NA	0.43 J	<0.23	0.27 J	0.12 J	0.11 J	0.13 J	<0.19	NA	0.35 J	<0.23	<0.23
Field pH, Std. Units	P	8.17		8.59	7.51	8.03	7.10	6.46	7.79	7.13	7.12	9.52	8.51	7.6	9.01	6.94	8.56	7.17	7.23
Sulfate, mg/L	P	457		42.1	128	78.7	31.8	NA	120	84	100	248	273	188	271	NA	140	220	250
Total Dissolved Solids, mg/L	P	1,113		436	502	520	462	NA	540	420	640	540	657	551	537	NA	460	710	750
Appendix IV		**UPL**	**GPS**																
Antimony, ug/L	P*	0.17	6	NA	<0.026	<0.15	<0.078	NA	<0.53	<0.53	<0.58	NA	0.75 J	0.3 J	0.77 J	NA	0.66 J	<0.53	<0.58
Arsenic, ug/L**	P	114.9	114.9	NA	7.9	52	29.8	NA	6.4	17	18	NA	57.2	45.4	58.3	NA	59	36	35
Barium, ug/L	P	1,147	2,000	NA	412	354	415	NA	440	440	610	NA	115	140	92	NA	90	210	220
Beryllium, ug/L	NP*	0.036	4	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27
Cadmium, ug/L	NP*	0.025	5	NA	0.028 J	<0.070	<0.033	NA	<0.077	<0.039	<0.039	NA	<0.018	<0.070	0.054 J	NA	<0.077	<0.039	<0.039
Chromium, ug/L	P*	0.090	100	NA	0.27 J, B	0.29 J	0.69 J	NA	<0.98	<0.98	<1.1	NA	0.22 J, B	0.34 J	0.091 J	NA	<0.98	<0.98	<1.1
Cobalt, ug/L	P	3.87	6	NA	0.31 J	0.46 J	0.62 J	NA	0.36 J	0.45 J	0.56	NA	0.098 J	<0.15	0.19 J	NA	0.11 J	0.13 J	0.15 J
Fluoride, mg/L	P	0.427	4	NA	0.22	0.44	0.27	NA	0.43 J	<0.23	0.27 J	NA	0.11 J	0.13 J	<0.19	NA	0.35 J	<0.23	<0.23
Lead, ug/L	NP*	0.64	15	NA	0.21 J	0.22 J	0.54 J,B	NA	0.49 J	<0.27	0.29 J	NA	<0.033	<0.12	<0.13	NA	<0.27	<0.27	<0.27
Lithium, ug/L	NP*	7.7	40	NA	**50.7**	**42.1**	35.8	**51.6**	**52**	**46**	**48**	NA	63.8	34.3	82.4	35.9	52	38	47
Mercury, ug/L	DQ	DQ	2	NA	<0.090	NA	<0.090	NA	<0.10	NA	<0.10	NA	<0.090	NA	<0.090	NA	<0.10	NA	0.11 J, F1
Molybdenum, ug/L	NP	14.7	100	NA	75.4	77.9	56.5	NA	110	76	66	NA	126	74.9	113	47.4	58	47	45
Selenium, ug/L	P*	0.28	50	NA	0.19 J	0.24 J	0.33 J	NA	<1.0	<1.0	<1.0	NA	0.24 J	0.21 J	0.26 J	NA	<1.0	<1.0	<1.0
Thallium, ug/L	NP*	0.35	2	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26
Radium 226/228 Combined, pCI/L	P	3.36	5	NA	1.64	1.79	1.91	NA	1.26	1.04	0.892	NA	0.589	0.725	0.706	NA	0.408	0.781	0.573

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Notes: See page 9

Table 1. Groundwater Analytical Results Summary - Compliance Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25220066.00

				Compliance Wells														
Parameter Name	**UPL Method**	**UPL**	**GPS**	**MW-305**							**MW-306**							
				10/16/2017	5/9/2018	8/13/2018	10/10/2018	4/3/2019	10/11/2019	6/3/2020	10/16/2017	5/9/2018	8/14/2018	10/10/2018	3/11/2019	4/3/2019	10/11/2019	6/4/2020
Appendix III																		
Boron, ug/L	NP	2,950		2,480	2,000	2,400	2,040	2,000	2,100	2,200	3,680	3,480	3,430	3,350	NA	2,900	3,100	3,200
Calcium, mg/L	P	210		92.2	82.5	103	93.2	83	90	120	35.3	32.0	33.5	34.6	NA	37	38	41
Chloride, mg/L	P	209		35.8	34.8	34.8	34.9	33	33	36	20.6	20.3	20.6	20.9	NA	21	20	21
Fluoride, mg/L	P	0.427		0.43	0.48	0.45	0.44	0.75	0.37 J	0.45 J	0.15 J	0.12 J	0.1 J	<0.19	NA	0.36 J	<0.23	<0.23
Field pH, Std. Units	P	8.17		7.78	7.72	7.81	7.29	7.80	7.36	7.12	10.66	6.80	10.33	6.04	6.27	6.69	10.53	10.48
Sulfate, mg/L	P	457		24.6	11.7	24.8	19.6	10	8.8	33	97.5	107	111	121	NA	110	110	120
Total Dissolved Solids, mg/L	P	1,113		437	441	542	490	470	490	640	301	396	303	289	NA	320	290	320
Appendix IV		**UPL**	**GPS**															
Antimony, ug/L	P*	0.17	6	NA	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58	NA	1.2	1.4	1.2	NA	1.1	1.2	1.1
Arsenic, ug/L**	P	114.9	114.9	NA	0.28 J	0.39 J	0.44 J	<0.75	<0.75	<0.88	NA	52.6	48	50.6	NA	50	46	50
Barium, ug/L	P	1,147	2,000	NA	173	219	197	160	180	230	NA	13.6	15.5	14.8	NA	14	14	16
Beryllium, ug/L	NP*	0.036	4	NA	<0.012	<0.12	<0.089	<0.27	<0.27	<0.27	NA	<0.012	0.14 J	<0.089	NA	<0.27	<0.27	<0.27
Cadmium, ug/L	NP*	0.025	5	NA	<0.018	<0.070	<0.033	<0.077	<0.039	<0.039	NA	0.029 J	0.18 J	<0.033	NA	<0.077	<0.039	<0.039
Chromium, ug/L	P*	0.090	100	NA	0.25 J, B	0.21 J	0.27 J	<0.98	<0.98	<1.1	NA	0.24 J, B	0.25 J	0.18 J	NA	<0.98	<0.98	<1.1
Cobalt, ug/L	P	3.87	6	NA	0.14 J	<0.15	0.17 J	0.16 J	0.13 J	0.18 J	NA	0.035 J	0.18 J	<0.062	NA	<0.091	<0.091	<0.091
Fluoride, mg/L	P	0.427	4	NA	0.48	0.45	0.44	0.75	0.37 J	0.45 J	NA	0.12 J	0.1 J	<0.19	NA	0.36 J	<0.23	<0.23
Lead, ug/L	NP*	0.64	15	NA	0.034 J	<0.12	0.20 J,B	<0.27	<0.27	<0.27	NA	0.26 J	0.69 J	0.37 J,B	NA	<0.27	0.44 J	0.33 J
Lithium, ug/L	NP*	7.7	40	NA	27.8	33.6	27.6	29	26	28	NA	36.6	46.8	41.4	39.2	45	46	43
Mercury, ug/L	DQ	DQ	2	NA	<0.090	NA	<0.090	<0.10	NA	0.12 J	NA	<0.090	NA	<0.090	NA	<0.10	NA	0.10 J
Molybdenum, ug/L	NP	14.7	100	NA	0.87 J	1.0	0.72 J	<1.1	<1.1	<1.1	NA	84.7	82.9	83.5	NA	78	84	86
Selenium, ug/L	P*	0.28	50	NA	0.24 J	0.16 J	0.16 J	<1.0	<1.0	<1.0	NA	0.66 J	0.97 J	0.6 J	NA	<1.0	<1.0	<1.0
Thallium, ug/L	NP*	0.35	2	NA	<0.036	NA	<0.099	<0.27	NA	<0.26	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26
Radium 226/228 Combined, pCI/L	P	3.36	5	NA	2.11	1.78	1.22	0.519	0.441	0.759	NA	0.482	1.04	1.10	NA	0.165	0.526	0.0769

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Notes: See page 9

Table 1. Groundwater Analytical Results Summary - Compliance Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25220066.00

Parameter Name	UPL Method	UPL	GPS	Compliance Wells															
				MW-307								MW-307A	MW-308						
				10/16/2017	5/9/2018	8/14/2018	10/10/2018	3/11/2019	4/3/2019	10/11/2019	6/4/2020	9/9/2020	10/17/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/4/2020
Appendix III																				
Boron, ug/L	NP	2,950		3,920	3,910	4,090	3,720	NA	3,400	3,700	3,600	3,900	4,850	5,030	5,070	4,710	NA	4,300	4,500	4,700
Calcium, mg/L	P	210		31.3	27.3	27.2	27.6	NA	29	31	37	10	32.6	28.7	28.7	28.5	NA	32	30	34
Chloride, mg/L	P	209		20.8	20.1	20.1	21.6	NA	21	19	21	34	38.2	36.2	36.7	35.9	NA	38	40	58
Fluoride, mg/L	P	0.427		0.13 J	0.11 J	0.094 J	<0.19	NA	0.51	<0.23	<0.23	<0.23	0.17 J	0.17 J	0.16 J	<0.19	NA	0.37 J	<0.23	0.37 J
Field pH, Std. Units	P	8.17		10.46	10.3	10.12	9.88	9.71	10.39	10.14	10.03	7.83	9.75	9.75	9.86	9.82	7.72	9.97	9.42	9.65
Sulfate, mg/L	P	457		126	119	119	143	NA	120	130	180	110	177	164	167	193	NA	170	160	190
Total Dissolved Solids, mg/L	P	1,113		341	347	340	336	NA	420	340	390	370	472	494	468	440	NA	490	400	470
Appendix IV		UPL	GPS																
Antimony, ug/L	P*	0.17	6	NA	0.50 J	0.58 J	0.62 J	NA	<0.53	<0.53	<0.58	<0.51	NA	0.32 J	0.32 J	0.36 J	NA	<0.53	<0.53	<0.58
Arsenic, ug/L**	P	114.9	114.9	NA	54.3	52.3	52.8	NA	43	47	47	<0.88	NA	79.1	82.5	79.5	NA	78	72	76
Barium, ug/L	P	1,147	2,000	NA	32.3	29	31.1	NA	29	31	36	45	NA	64.3	67.1	66.5	NA	70	70	66
Beryllium, ug/L	NP*	0.036	4	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27	<0.27	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27
Cadmium, ug/L	NP*	0.025	5	NA	0.12 J	<0.070	0.068 J	NA	<0.077	<0.039	0.044 J	0.058 J	NA	0.020 J	<0.070	0.058 J	NA	<0.077	<0.039	0.044 J
Chromium, ug/L	P*	0.090	100	NA	0.27 J, B	0.36 J	0.15 J	NA	<0.98	<0.98	<1.1	<1.1	NA	0.25 J, B	<0.19	0.16 J	NA	<0.98	<0.98	<1.1
Cobalt, ug/L	P	3.87	6	NA	0.033 J	<0.15	<0.062	NA	<0.091	<0.091	<0.091	0.11 J	NA	0.057 J	<0.15	0.074 J	NA	<0.091	<0.091	<0.091
Fluoride, mg/L	P	0.427	4	NA	0.11 J	0.094 J	<0.19	NA	0.51	<0.23	<0.23	<0.23	NA	0.17 J	0.16 J	<0.19	NA	0.37 J	<0.23	0.37 J
Lead, ug/L	NP*	0.64	15	NA	0.39 J	0.43 J	0.49 J,B	NA	0.37 J	0.41 J	<0.27	0.69	NA	0.25 J	0.27 J	0.45 J,B	NA	<0.27	<0.27	0.40 J
Lithium, ug/L	NP*	7.7	40	NA	**47.8**	**56.1**	**45.4**	**50.7**	**50**	**48**	**48**	6.8 J	NA	**46.0**	**52.0**	**43.6**	**48.9**	**50**	**52**	**48**
Mercury, ug/L	DQ	DQ	2	NA	<0.090	NA	<0.090	NA	<0.10	NA	0.12 J	<0.10	NA	<0.090	NA	<0.090	NA	<0.10	NA	0.13 J
Molybdenum, ug/L	NP	14.7	100	NA	**154**	**155**	**159**	**156**	**100**	**130**	**130**	**110**	NA	**140**	**140**	**145**	**135**	**110**	**120**	**120**
Selenium, ug/L	P*	0.28	50	NA	0.36 J	0.41 J	0.36 J	NA	<1.0	<1.0	<1.0	<1.0	NA	0.31 J	0.43 J	0.4 J	NA	<1.0	<1.0	<1.0
Thallium, ug/L	NP*	0.35	2	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26	<0.26	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26
Radium 226/228 Combined, pCl/L	P	3.36	5	NA	0.0587	0.415	1.43	NA	0.447	0.232	0.277	pending	NA	0.283	0.0726	0.334	NA	0.328	0.288	0.268

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Notes: See page 9

Table 1. Groundwater Analytical Results Summary - Compliance Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25220066.00

Parameter Name	UPL Method	UPL	GPS	Compliance Wells													
				MW-309							MW-312			MW-313			MW-313A
				10/17/2017	5/9/2018	8/14/2018	10/10/2018	4/3/2019	10/11/2019	6/3/2020	6/6/2019	10/10/2019	6/3/2020	6/6/2019	10/10/2019	6/3/2020	9/9/2020
Appendix III																	
Boron, ug/L	NP	2,950		4,400	4,720	4,930	4,720	4,200	4,300	4,400	6,100	6,600	6,700	7,400	8,500	8,600	4,300
Calcium, mg/L	P	210		101	83.6	74.1	72.4	73	68	82	67	71	74	110	120	120	48
Chloride, mg/L	P	209		85.4	112	111	105	100	74	84	27	25	36	85	51	83	210
Fluoride, mg/L	P	0.427		0.47	0.40	0.43	0.40	0.71	0.29 J	0.58	1.1	0.25 J	0.57	0.33 J	0.28 J	0.52	<0.23
Field pH, Std. Units	P	8.17		8.50	7.25	7.39	7.46	7.45	7.19	7.09	6.99	7.19	7.13	6.94	7.06	7.03	7.6
Sulfate, mg/L	P	457		149	107	98.9	111	78	160	180	220	230	200	210	210	230	200
Total Dissolved Solids, mg/L	P	1,113		671	688	668	650	650	610	730	540	510	670	700	520	830	730
Appendix IV		**UPL**	**GPS**														
Antimony, ug/L	P*	0.17	6	NA	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58	<0.53	<0.53	<0.58	<0.53	<0.53	<0.58	<0.51
Arsenic, ug/L**	P	114.9	114.9	NA	28.2	33.3	35.6	30	34	34	14	15	22	5.5	6.3	6.9	<0.88
Barium, ug/L	P	1,147	2,000	NA	154	180	194	130	180	260	160	150	190	510	490	680	270
Beryllium, ug/L	NP*	0.036	4	NA	0.012 J	<0.12	<0.089	<0.27	<0.54	<0.27	<0.27	<0.54	<0.27	<0.27	<1.1	<0.27	<0.27
Cadmium, ug/L	NP*	0.025	5	NA	0.021 J	<0.070	<0.033	<0.077	<0.039	<0.039	<0.077	0.044 J	0.095 J	<0.077	<0.039	0.039 J	<0.049
Chromium, ug/L	P*	0.090	100	NA	0.32 J, B	0.22 J	0.18 J	<0.98	<0.98	<1.1	<0.98	<0.98	<1.1	<0.98	<0.98	<1.1	<1.1
Cobalt, ug/L	P	3.87	6	NA	4.9	0.82 J	0.68 J	1.3	0.52	0.57	0.65	0.36 J	0.67	0.41 J	0.32 J	0.23 J	<0.091
Fluoride, mg/L	P	0.427	4	NA	0.40	0.43	0.40	0.71	0.29 J	0.58	1.1	0.25 J	0.57	0.33 J	0.28 J	0.52	<0.23
Lead, ug/L	NP*	0.64	15	NA	0.045 J	<0.12	<0.13	<0.27	<0.27	<0.27	0.54	<0.27	<0.27	<0.27	0.31 J	<0.27	<0.11
Lithium, ug/L	NP*	7.7	40	NA	<4.6	<4.6	<4.6	3.3 J	<5.4	2.4 J	24	27	22	43	62	52	13
Mercury, ug/L	DQ	DQ	2	NA	<0.090	NA	<0.090	<0.10	NA	<0.10	<0.10	NA	<0.10	<0.10	NA	0.13 J	<0.10
Molybdenum, ug/L	NP	14.7	100	NA	43.4	52.8	71.8	47	90	87	290	280	320	130	110	130	120
Selenium, ug/L	P*	0.28	50	NA	0.30 J	0.31 J	0.29 J	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thallium, ug/L	NP*	0.35	2	NA	<0.036	NA	<0.099	<0.27	NA	<0.26	<0.27	NA	<0.26	<0.27	NA	<0.26	<0.26
Radium 226/228 Combined, pCI/L	P	3.36	5	NA	0.218	0.96	1.05	0.42	0.596	0.296	0.875	0.438	0.543	0.987	1.70	1.81	pending

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17	Yellow highlighted cell with bold text indicates the compliance well result exceeds the GPS and the result was determined to be statistically significant(1).

Notes: See page 9

Table 2. Results Comparison to GPS for Lithium
IPL - Burlington Generating Station / SCS Engineers Project #25220066.00

Monitoring Well	Units	Groundwater Protection Standard (GPS)	Assessment Monitoring Results: 5/8/2018 and 5/9/2018	8/13/2018 and 8/14/2018	10/9/2018 and 10/10/2018	3/11/2019 and 3/12/2019	4/3/2019 and 4/4/2019	6/6/2019	10/10/2019 and 10/11/2019	6/3/2020 and 6/4/2020	Mean	Lower Confidence Limit for Mean (a = 95%)	LCL Exceeds GPS?
MW-302	ug/L	40	65.4	61.4	57.8	59.9	56	--	57	55	58.9	56.3	YES
MW-303	ug/L	40	50.7	42.1	35.8	51.6	52	--	46	48	46.6	42.2	YES
MW-304	ug/L	40	63.8	34.3	82.4	35.9	52	--	38	47	50.5	37.5	NO
MW-306	ug/L	40	36.6	46.8	41.4	39.2	45	--	46	43	42.6	39.8	NO
MW-307	ug/L	40	47.8	56.1	45.4	50.7	50	--	48	48	49.4	46.9	YES
MW-308	ug/L	40	46.0	52.0	43.6	48.9	50	--	52	48	48.6	46.4	YES
MW-313	ug/L	40	--	--	--	--	--	43	62	52	52.3	NA	NA

40.0 Result exceeds GPS

-- = Not sampled NA = Not applicable (LCL requires at least 4 results)

Note: Table includes wells where lithium has been detected above the GPS during at least one assessment monitoring event.

Created by: SCC Date: 4/12/2019
Last revision by: NDK Date: 7/21/2020
Checked by: MDB Date: 7/29/2020
Scientist or Proj Mgr QA/QC: TK Date: 7/31/2020

I:\25219168.00\Deliverables\EPA Closure App\Tables\[Tables 2 and 3 _LCL Calc Table BGS.xlsx]T2 Li

Table 3. Results Comparison to GPS for Molybdenum
IPL - Burlington Generating Station / SCS Engineers Project #25220066.00

Monitoring Well	Units	Groundwater Protection Standard (GPS)	Assessment Monitoring Results: 5/8/2018 - 5/9/2018	8/13/2018 - 8/14/2018	10/9/2018 - 10/10/2018	3/11/2019 - 3/12/2019	4/3/2019 - 4/4/2019	6/6/2019	10/10/2019 - 10/11/2019	6/3/2020 - 6/4/2020	Mean	Lower Confidence Limit for Mean (a = 95%)	LCL Exceeds GPS?
MW-301	ug/L	100	113	81.7	120	62.7	77	--	130	110	99.2	80.5	NO
MW-302	ug/L	100	118	121	122	123	100	--	100	140	118	107	YES
MW-303	ug/L	100	75.4	77.9	56.5	-	110	--	76	66	77.0	62.5	NO
MW-304	ug/L	100	126	74.9	113	47.4	58	--	47	45	73.0	48.2	NO
MW-307	ug/L	100	154	155	159	156	100	--	130	130	141	124	YES
MW-308	ug/L	100	140	140	145	135	110	--	120	120	130	120	YES
MW-312	ug/L	100	--	--	--	--	--	290	280	320	297	NA	NA
MW-313	ug/L	100	--	--	--	--	--	130	110	130	123	NA	NA

113 Result exceeds GPS

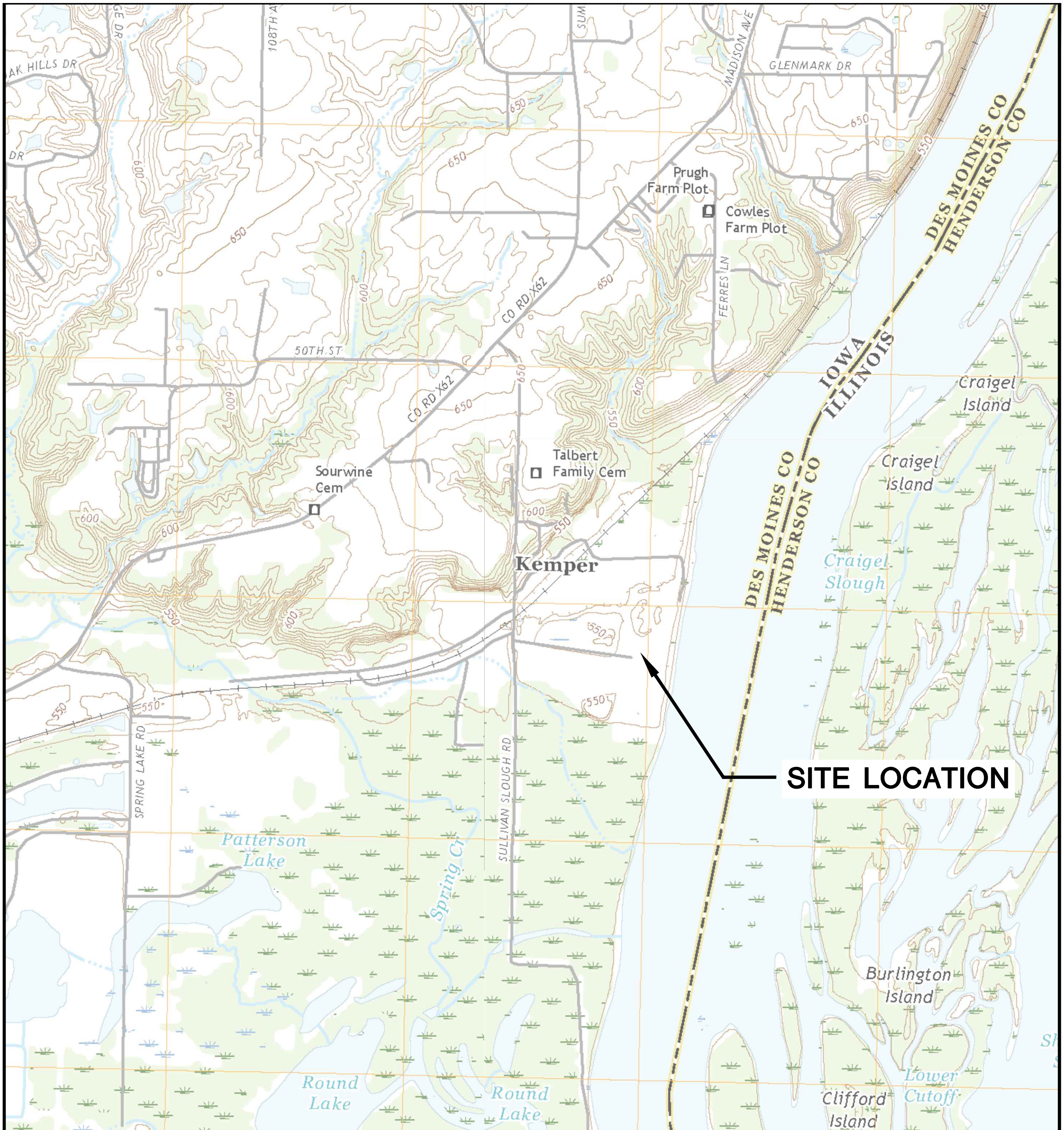
-- = Not sampled NA = Not applicable (LCL requires at least 4 results)

Note: Table includes wells where molybdenum has been detected above the GPS during at least one assessment monitoring event.

Created by: SCC Date: 4/12/2019
Last revision by: NDK Date: 7/21/2020
Checked by: MDB Date: 7/29/2020
Scientist or Proj Mgr QA/QC: TK Date: 7/31/2020

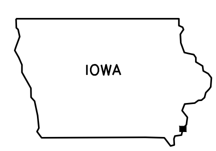
I:\25219168.00\Deliverables\EPA Closure App\Tables\[Tables 2 and 3 _LCL Calc Table BGS.xlsx]T3 Mo

Figures



N

LOMAX QUADRANGLE
ILLINOIS / IOWA-DES MOINES CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
2018
SCALE: 1" = 2,000'



CLIENT	ALLIANT ENERGY 4902 N. BILTMORE LANE, #1000 MADISON, WI 53718	SITE	ALLIANT ENERGY BURLINGTON GENERATING STATION BURLINGTON, IOWA	SITE LOCATION MAP

PROJECT NO.	25220066.00	DRAWN BY:	BSS	ENGINEER	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	FIGURE
DRAWN:	11/14/2019	CHECKED BY:	MDB			1
REVISED:	03/12/2020	APPROVED BY:	TK 03/12/2020			

I:\25220066.00\Drawings\Site Location Map.dwg, 3/12/2020 10:13:36 AM

LEGEND

- EXISTING CCR RULE MONITORING WELL
- EXISTING CCR RULE PIEZOMETER
- CCR UNITS
- **BACKGROUND MONITORING WELL**

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW-301, MW-302, AND MW-309 THROUGH MW-311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
4. 2018 AERIAL PHOTOGRAPH SOURCES: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA FSA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY.

PROJECT NO.	25220081.00	DRAWN BY:	RJG
DRAWN:	11/14/2019	CHECKED BY:	MDB/EJN
REVISED:	10/16/2020	APPROVED BY:	EJN, 11/23/20

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY
4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

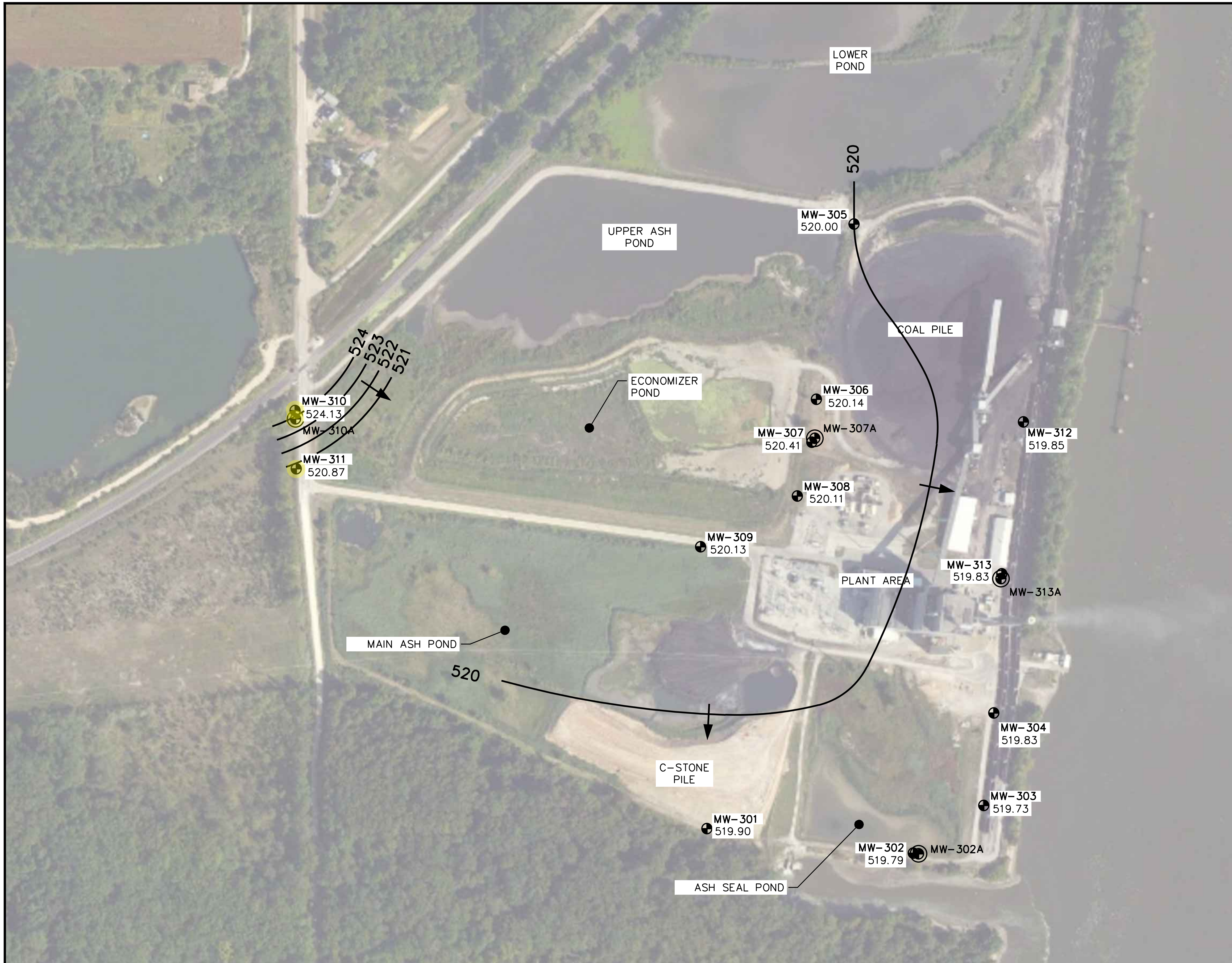
SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

SITE PLAN AND MONITORING WELL LOCATIONS

FIGURE 2

I:\25219168.00\Drawings\...ite Plan and Monitoring Well Locations.dwg, 11/23/2020 10:...

11/25/2020 - Classification: Internal - ECRM7803923



LEGEND

- MONITORING WELL
- DEEP PIEZOMETER
- ELEVATION CONTOUR
- APPROXIMATE FLOW DIRECTION
- **BACKGROUND MONITORING WELL**

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW301, MW302, AND MW309-MW311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-301 THROUGH MW-311 WERE SURVEYED BY FRENCH-RENEKER ASSOCIATES OF FRANKLIN, IA ON MARCH 16, 2016.
4. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
5. DEEP PIEZOMETERS MW-302A, MW-307A, MW-310A, AND MW-313A WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN JUNE-JULY 2020.
6. GROUNDWATER ELEVATION ESTIMATED BASED ON MONITORING WELLS SCREENED BELOW THE POTENTIOMETRIC SURFACE IN THE SAND UNIT.

N

300 0 300

SCALE: 1" = 300'

PROJECT NO.	252191680	DRAWN BY:	BSS/KP
DRAWN:	09/18/2020	CHECKED BY:	MDB
REVISED:	09/24/2020	APPROVED BY:	TK 10/21/20

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

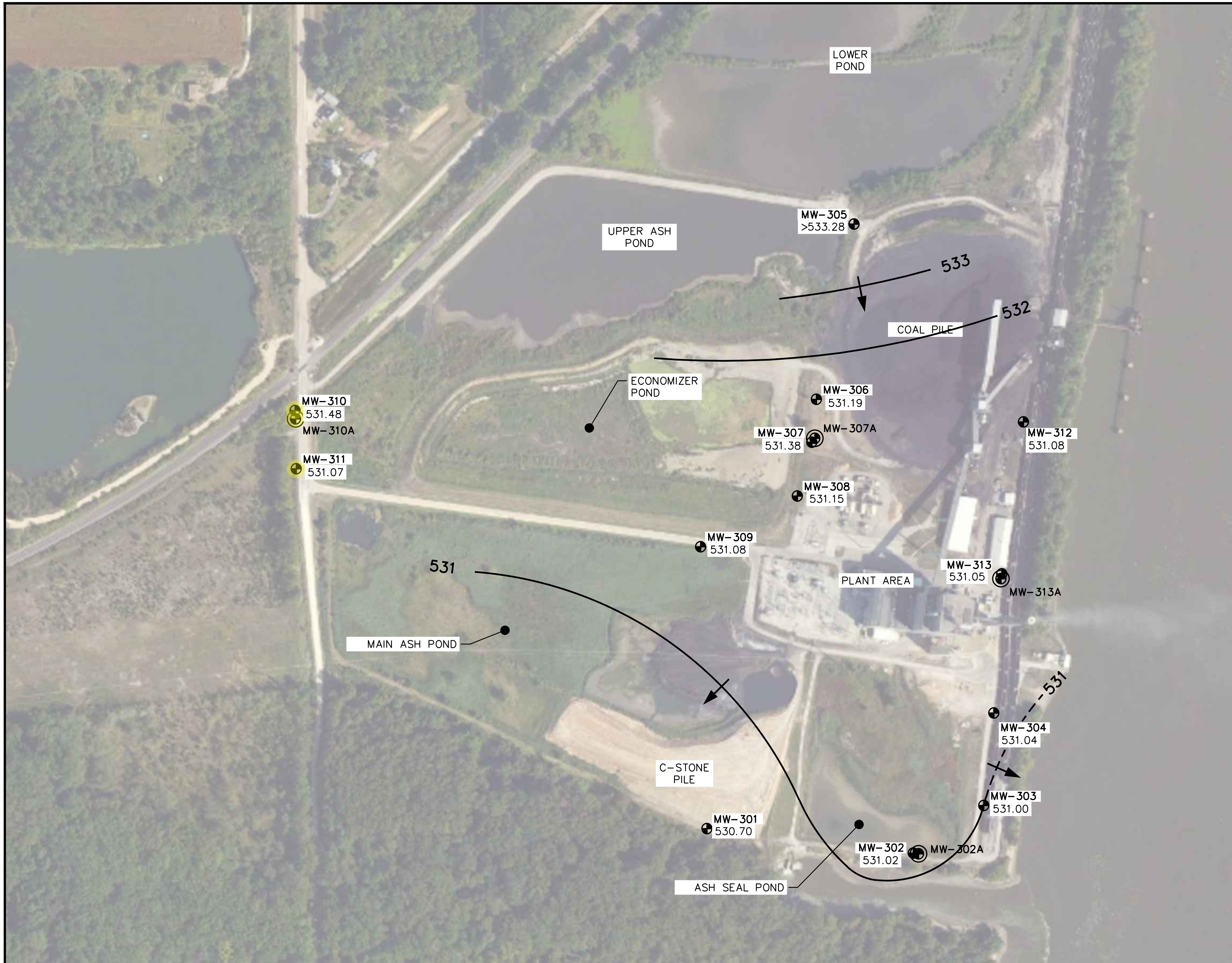
CLIENT: ALLIANT ENERGY
4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

LOW POTENTIOMETRIC SURFACE MAP
SEPTEMBER 9, 2020

FIGURE 3

11/25/2020 - Classification: Internal - ECRM7803923



LEGEND

- MONITORING WELL
- DEEP PIEZOMETER
- WATER TABLE ELEVATION CONTOUR (DASHED WHERE INFERRED)
- APPROXIMATE FLOW DIRECTION
- **BACKGROUND MONITORING WELL**

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW301, MW302, AND MW309-MW311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-301 THROUGH MW-311 WERE SURVEYED BY FRENCH-RENEKER ASSOCIATES OF FRANKLIN, IA ON MARCH 16, 2016.
4. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
5. DEEP PIEZOMETERS MW-302A, MW-307A, MW-310A, AND MW-313A WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN JUNE-JULY 2020.
6. GROUNDWATER ELEVATION ESTIMATED BASED ON MONITORING WELLS SCREENED BELOW THE POTENTIOMETRIC SURFACE IN THE SAND UNIT.

PROJECT NO.	252191680	DRAWN BY:	BSS/KP
DRAWN:	09/18/2020	CHECKED BY:	MDB
REVISED:	09/24/2020	APPROVED BY:	TK 10/21/20

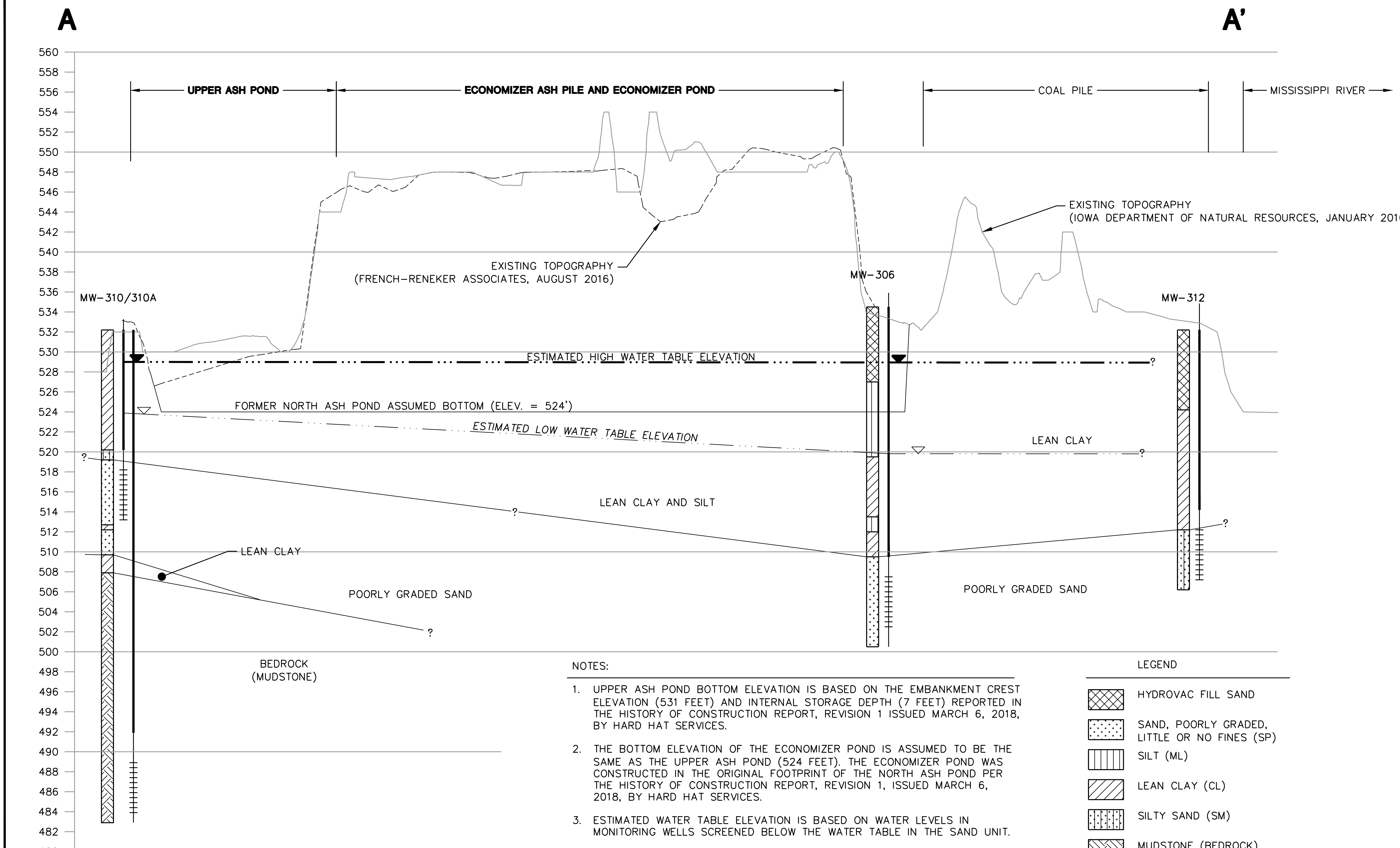
ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY
4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

HIGH POTENTIOMETRIC SURFACE MAP
JUNE 6, 2019

FIGURE 4

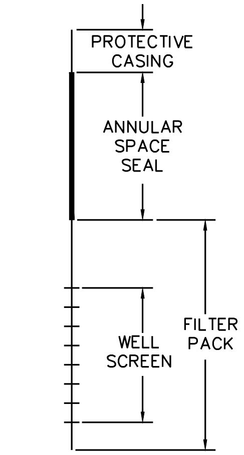


NOTES:

1. UPPER ASH POND BOTTOM ELEVATION IS BASED ON THE EMBANKMENT CREST ELEVATION (531 FEET) AND INTERNAL STORAGE DEPTH (7 FEET) REPORTED IN THE HISTORY OF CONSTRUCTION REPORT, REVISION 1 ISSUED MARCH 6, 2018, BY HARD HAT SERVICES.
2. THE BOTTOM ELEVATION OF THE ECONOMIZER POND IS ASSUMED TO BE THE SAME AS THE UPPER ASH POND (524 FEET). THE ECONOMIZER POND WAS CONSTRUCTED IN THE ORIGINAL FOOTPRINT OF THE NORTH ASH POND PER THE HISTORY OF CONSTRUCTION REPORT, REVISION 1, ISSUED MARCH 6, 2018, BY HARD HAT SERVICES.
3. ESTIMATED WATER TABLE ELEVATION IS BASED ON WATER LEVELS IN MONITORING WELLS SCREENED BELOW THE WATER TABLE IN THE SAND UNIT.
4. MW-306 AND MW-312 WERE HYDROVACED TO APPROXIMATELY 8 FEET. HYDROVACING IS PERFORMED TO DETERMINE IF UNDERGROUND UTILITIES ARE PRESENT. HIGH PRESSURE WATER AND A VACUUM ARE USED TO CLEAR THE BOREHOLE. AFTER HYDROVACING WAS COMPLETE THE BOREHOLE WAS FILLED WITH SAND TO COMPLETE THE BOREHOLE DRILLING PROCESS.

LEGEND

- HYDROVAC FILL SAND
- SAND, POORLY GRADED, LITTLE OR NO FINES (SP)
- SILT (ML)
- LEAN CLAY (CL)
- SILTY SAND (SM)
- MUDSTONE (BEDROCK)
- WATER LEVEL AT MONITORING WELL, APRIL 2019
- WATER LEVEL AT MONITORING WELL, AUGUST 2017



WELL DETAIL

0 200

HORIZONTAL SCALE: 1" = 200'
VERTICAL SCALE: 1" = 10'
VERTICAL EXAGGERATION = 20X

PROJECT NO.	25219168.00	DRAWN BY:	KP
DRAWN:	06/12/2019	CHECKED BY:	MDB
REVISED:	09/24/2020	APPROVED BY:	EJN, 11/23/20

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY
4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

GEOLOGIC CROSS SECTION

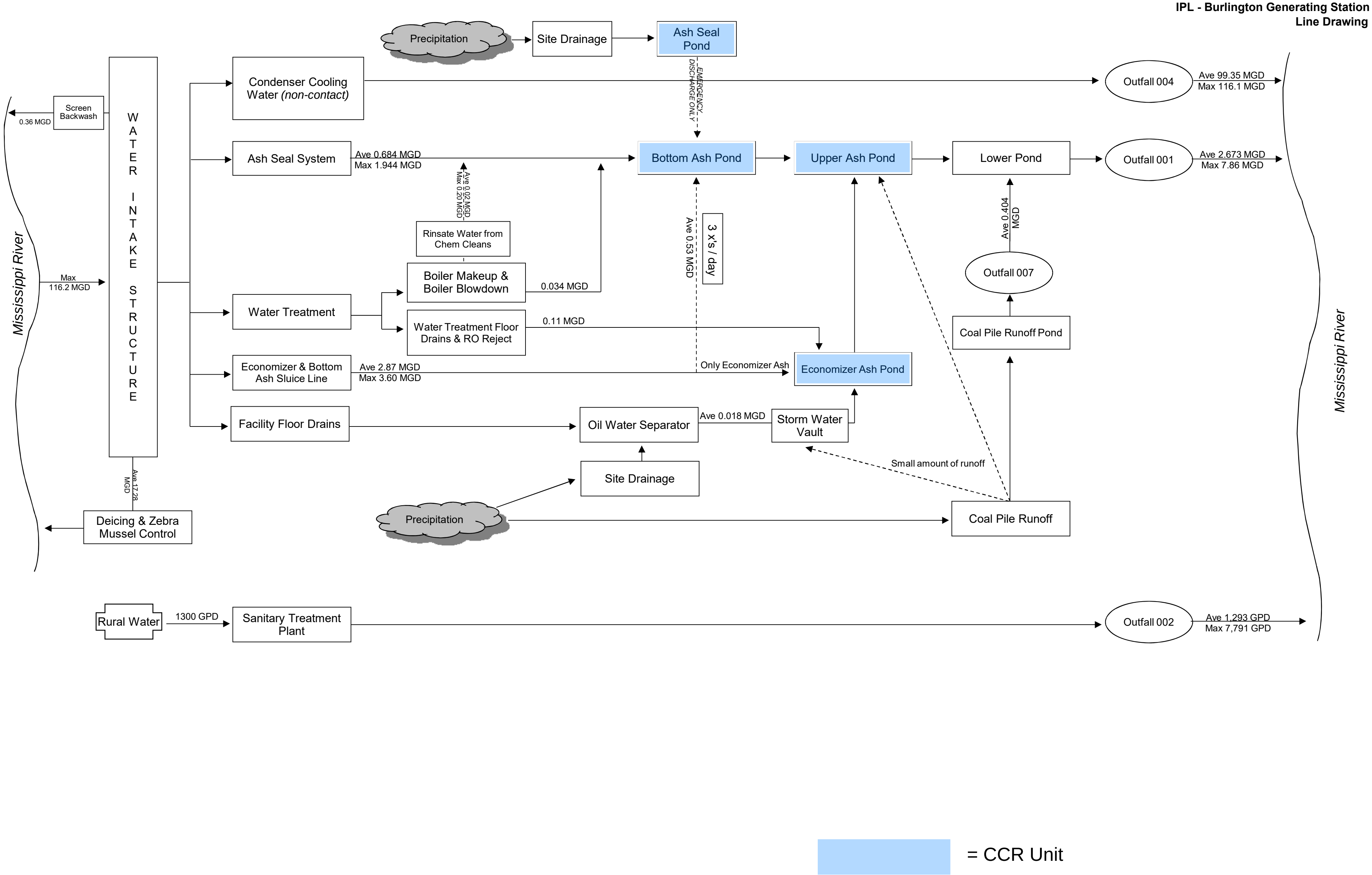
FIGURE
5

I:\25219168.00\Drawings\ P los re\ ross ection.dwg, 9/24/2020 9:49:42 M

11/25/2020 - Classification: Internal - ECRM7803923

Figure 6

IPL - Burlington Generating Station
Line Drawing



Source: NPDES Permit Renewal Application, Interstate Power and Light ("IPL") – Burlington Generating Station NPDES Permit No.: 2900101, October 18, 2019

PROJECT NO.	25219168.00	DRAWN BY:	KP
DRAWN:	11/23/2020	CHECKED BY:	BSS/RJG
REVISED:	11/23/2020	APPROVED BY:	EJN, 11/23/20

INTERSTATE POWER AND LIGHT CO.
4282 SULLIVAN SLOUGH ROAD
BURLINGTON, IA 52601

CLIENT

SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

ENGINEER

ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

SITE

OVERALL SITE PLAN

FIGURE
7

Appendix A

Owner's Compliance Certification

OWNER OR OPERATOR CERTIFICATION OF COMPLIANCE

In accordance with 40 C.F.R. § 257.103(f)(2)(v)(C)(1), I hereby certify, based on information provided to me by, and my inquiry of, persons immediately responsible for compliance with the CCR rule at the Burlington Generating Station, that the Burlington Generating Station, including the existing CCR surface impoundments, is in compliance with 40 C.F.R. Part 257, Subpart D – Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments. All the required CCR compliance information for the Burlington Generating Station is up-to-date and posted on the Alliant Energy CCR Rule Data and Compliance website.

John Watts
Name

John Watts
Signature

PLANT MANAGER
Title

23 NOV 2020
Date

Appendix B

Hydrogeological and Groundwater Monitoring Data

B1 Boring Logs and Well Construction Forms

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION

Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-301

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	2/29/2016	2/29/2016	Direct Push 4-1/2/HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-301	Feet	535.98 Feet	8.5 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,382 N, 2,300,041 E S/C/N
SW 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' "
Long ° ' "
Local Grid Location: Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
S1	16		10–14	LEAN CLAY WITH SAND, very dark gray (10YR 3/1).	CL					W				
S2	45		14–15							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: (608) 224-2830 Fax:

This form is authorized by Chapters 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats. Completion of this form is mandatory. Failure to file this form may result in forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on this form is not intended to be be used for any other purpose. NOTE: See instructions for more information, including where the completed form should be sent.

Boring Number MW-301 Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			16–17		CL									
S3	37		18–19	POORLY GRADED SAND, very dark gray (10YR 3/1).	SP					W				
			19–21	SILT WITH SAND, very dark gray (10YR 3/1).	ML									
			21–22	POORLY GRADED SAND, very dark gray (10YR 3/1).	SP									
S4	24		22–24	SANDY SILT, very dark gray (10YR 3/1).	MLS					W				
S5	NA		24–29	POORLY GRADED SAND, very dark gray (10YR 3/1).	SP					W				Recovery NA sleeve stuck in discrete sampler.
				End of Boring at 29.50 feet bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION
Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name		License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80			MW-302

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	2/29/2016	2/29/2016	Direct Push 4-1/2/HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-302	Feet	533.24 Feet	8.5 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,310 N, 2,300,647 E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' "
Long ° ' "
Local Grid Location: Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
S1	15		10–12	POORLY GRADED SAND WITH SILT, medium grained, very dark gray (10YR 3/1).	SP-SM					W				
S2	15		12–15	POORLY GRADED SAND, medium grained, very dark gray (10YR 3/1).	SP					W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: (608) 224-2830 Fax:

This form is authorized by Chapters 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats. Completion of this form is mandatory. Failure to file this form may result in forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on this form is not intended to be used for any other purpose. NOTE: See instructions for more information, including where the completed form should be sent.

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-302 Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			16		SP									
S3	17		17–19	LEAN CLAY, very dark gray (10YR 3/1).	CL					W				
S4	15		20–23	POORLY GRADED SAND, coarse grained, very dark gray (10YR 3/1).	SP					W				
S5	16		24–27							W				
			28	End of Boring at 28 feet bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION

Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Burlington Generating Station SCS#: 25220055.00		MW-302A

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Crank Roberts Environmental Services	6/30/2020	7/1/2020	4.25" HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			11.92 Feet	533.51 Feet MSL	8.0 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,310 N, 2,300,647 E S / C / N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W

Lat ___ ° ___ ' ___ "
Long ___ ° ___ ' ___ "

Local Grid Location
Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
	0		0–15	Blind drilled to 28' bgs See boring logs for MW-302 for log information from 0-25'bgs.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
	SCS Engineers	Tel: Fax:

This form is authorized by Chapters 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats. Completion of this form is mandatory. Failure to file this form may result in forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on this form is not intended to be be used for any other purpose. NOTE: See instructions for more information, including where the completed form should be sent.

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-302A Use only as an attachment to Form 4400-122.

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			16–24											
S1	14	3 4 7 8	25–27	POORLY GRADED SAND, mostly fine to meium grain, trace coarse grain, gray to dark gray (5y, 4/1) , with clay lense at top of spoon. olive gray, dense.	SP					W				
S2	3	0 2 4 5	30–32	Same, fine grain, trace coarse grain with large piece of limestone.						W				Roberts began using water to keep sand from backing up into augers. Took two jar samples from 25-27' bgs.
S3	0	6 8 7 8	35–37	No returns						W				
			38–40											

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number **MW-302A** Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
S4	6	5 7 8 13	41	POORLY GRADED SAND, fine to coarse grain, with gravel, gray to dark gray (5y, 3/1), with very trace silt (same color).						W				
			42											
			43											
			44											
			45	No returns										
S5	0	4 12 16 14	46							W				Roberts changed spoon catch.
			47											
			48											
			49											
			50	POORLY GRADED SAND, fine to coarse grain, trace gravel, gray to darkish gray brown, 5y, 4/1).	SP									
S6	15	3 8 12 14	51							W				
			52											
			53											
			54											
			55	Same										
S7	14	3 6 12 18	56							W				Took two jar samples from 55-57' bgs.
			57											
			58											
			59											
			60	Same										
S8	24	6 9 13 25	61	End of Boring at 61' below ground surface. Well placed at 60' bgs.						W				Sampled to 62' bgs and augered to 61' bgs.

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION
Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name: IPL- Burlington Generating Station SCS#: 25215135.80		License/Permit/Monitoring Number		Boring Number: MW-303	
Boring Drilled By: Name of crew chief (first, last) and Firm: Mike Mueller, Cascade Drilling		Date Drilling Started: 12/15/2015	Date Drilling Completed: 12/15/2015		Drilling Method: 4-1/2 hollow stem auger
WI Unique Well No.	DNR Well ID No.	Common Well Name: MW-303	Final Static Water Level: Feet	Surface Elevation: 531.01 Feet	Borehole Diameter: 8.5 in.
Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒ State Plane 278,450 N, 2,300,854 E S/C/N SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W		Lat ° ' " Long ° ' "		Local Grid Location Feet ☐ N ☐ S Feet ☐ E ☐ W	
Facility ID	County: Des Moines	County Code	Civil Town/City/ or Village: Burlington		

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
			10–15	LEAN CLAY, dark gray (10YR 3/1).	CL									
S1	0	4 6 8 8	11											Rock in the end of shoe.
S2	14	2 4 4 5	14							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]	Firm: SCS Engineers, 2830 Dairy Drive Madison, WI 53718	Tel: (608) 224-2830 Fax:

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SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-303 Use only as an attachment to Form 4400-122.

Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
S3	15	2 2 4 6	16–17		CL					W				
S4	3	1 2 3 8	18–19							W				Rock in the end of shoe.
S5	10	4 8 9 9	20–22	POORLY GRADED SAND, coarse grained, very dark gray (2.5Y 3/1), some gravel.	SP					W				
S6	14	1 2 8 9	23–24	POORLY GRADED SAND, very dark gray (2.5Y 3/1), medium grained.	SP					W				
S7	8	4 6 8 10	25–27	same as above except, coarse grained.						W				
				End of Boring at 27.50 ft bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION
Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Field	Value
Facility/Project Name	IPL- Burlington Generating Station SCS#: 25215135.80
License/Permit/Monitoring Number	
Boring Number	MW-304
Boring Drilled By: Name of crew chief (first, last) and Firm	Mike Mueller, Cascade Drilling
Date Drilling Started	12/15/2015
Date Drilling Completed	12/15/2015
Drilling Method	4-1/2 hollow stem auger
WI Unique Well No.	
DNR Well ID No.	
Common Well Name	MW-304
Final Static Water Level	Feet
Surface Elevation	532.15 Feet
Borehole Diameter	8.5 in.
Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒	State Plane 278,721 N, 2,300,883 E S/C/N
	SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat / Long	° ' " / ° ' "
Local Grid Location	Feet ☐ N ☐ S; Feet ☐ E ☐ W
Facility ID	
County	Des Moines
County Code	
Civil Town/City/ or Village	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
			10	FAT CLAY, dark gray (10YR 3/1).	CH									
S1	12	3 4 11 14	11							W				
S2		2 3 5 5	14							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]
Firm: SCS Engineers, 2830 Dairy Drive Madison, WI 53718
Tel: (608) 224-2830
Fax:

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SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-304 Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
S3	14	1 1 2 4	16, 17	SANDY SILT, very dark gray (2.5Y 3/1), fine grained.	ML					W				
S4	14	1 2 3	18, 19	POORLY GRADED SAND, very dark gray (2.5Y 3/1), medium grained.	SP					W				
S5	24	2 3 5 8	20, 21, 22							W				
S6	12	3 5 6 7	23, 24	Same as above except, coarse grained.						W				
S7	12	3 6 11 16	25, 26, 27							W				
				End of boring at 27 feet bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION
Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name		License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80			MW-305

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/17/2015	12/17/2015	4-1/2 hollow stem auger

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-305	Feet	530.85 Feet	8.5 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 280,157 N, 2,300,473 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' "
Long ° ' "
Local Grid Location: Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–5	FILL, boring location was cleared to 5' bgs by hydrovac, then back filled.	FILL									
			5	SILT, ash, black (2.5Y 2.5/1), (fill).	ML									
S1	14	13 30 20 12	6							M				
S2	6	3 4 2 1	8–9							M				
			10	LEAN CLAY, olive (5Y 4/4).	CL									
S3	5	4 4 6 7	11							M				
S4	10	2 4 6 8	13	same as above except, black (2.5Y 2.5/1).						M				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature] Firm: SCS Engineers, 2830 Dairy Drive Madison, WI 53718 Tel: (608) 224-2830 Fax:

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-305 Use only as an attachment to Form 4400-122.

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
S5	14	1 1 2 3	16											
			17		CL									
S6	16	1 1 2 2	18–19	same as above except, very dark gray (10YR 3/1).										
S7	12	1 2 4 5	20–21	POORLY GRADED SAND, very dark gray (10YR 3/1), coarse grained.						W				
			22											
S8	12	1 1 2 3	23–24		SP					W				
S9	8		25–27							W				
				End of Boring at 27.50 ft bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION

Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-306

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/16/2015	12/17/2015	4-1/2 hollow stem auger

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-306	Feet	534.51 Feet	8.5 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,643 N, 2,300,362 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' "
Long ° ' "
Local Grid Location: Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample: Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–7.5	FILL, boring location was cleared to 7.5' bgs by hydrovac, then back filled.	FILL									
			7.5	SANDY SILT, very dark gray (2.5Y 3/1), fine grained sand.	ML									
S1	22	6 8 12 12	8–10											
S2	22	7 2 2 2	10.5–12.5							W				
S3	12	4 9 19 21	13–15							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: (608) 224-2830 Fax:

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Department of Natural Resources

SOIL BORING LOG INFORMATION SUPPLEMENT

Form 4400-122A

Boring Number MW-306 Use only as an attachment to Form 4400-122.

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
				LEAN CLAY, black (2.5Y 2.5/1).	CL									
S4	10	2 2 2 2	16							W				
			17											
			18											
S5	10	1 1 1 2	19							W				
			20											
S6	22	3 4 5	21	SANDY SILT, very dark gray (2.5 3/1), fined grained sand.	ML					W				
			22											
			23	LEAN CLAY, black (2.5Y 2.5/1).	CL									
S7	10	1 1 1 2	24							W				
			25	POORLY GRADED SAND, very dark gray (2.5Y 3/1), coarse grained.	SP									
S8	20	2 3 6 10	26							W				
			27											
			28											
S9	10	1 3 3 5	29							W				
			30											
S10	10	2 2 3 8	31							W				
			32											
			33											
			34	End of boring at 34 ft bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION

Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-307

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/16/2015	12/16/2015	4-1/2 hollow stem auger

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-307	Feet	534.32 Feet	8.5 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,517 N, 2,300,349 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W

Lat ° ' "
Long ° ' "

Local Grid Location
Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	FILL, boring location was cleared to 7.5' bgs by hydrovac, then back filled.	FILL									
S1	0		7.5	SILT, ash, (fill).	ML									
S2	16	13 8 6 11	10	SANDY SILT, very dark gray (2.5Y 3/1), sand is fine grained.	ML					W				
S3	15	4 9 6 3								W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]
Firm: SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: (608) 224-2830
Fax:

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-307 Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
S4	18	1 3 5 5	16, 17		ML					W				
S5	20	1 2 2 2	18, 19	LEAN CLAY, black (10YR 2/1).	CL					W				
S6	16	1 2 4 6	20, 21, 22	POORLY GRADED SAND, very dark gray (2.5Y 3/1), coarse grained.						W				
S7	10	1 2 4 4	23, 24		SP					W				
S8	12	2 2 3 4	25, 26							W				
			27	End of boring at 27 ft bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION
Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Burlington Generating Station SCS#: 25220055.00		MW-307A

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Crank Roberts Environmental Services	6/24/2020	7/1/2020	4.25" HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			12.09 Feet	533.94 Feet MSL	8.0 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,517 N, 2,300,349 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ____° ____' ______"
Long ____° ____' ______"
Local Grid Location: Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
	0		0–15	Blind drilled to 20' bgs See boring logs for MW-307 for log information from 0-20'bgs.										

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Signature	Firm	
[signature]	SCS Engineers	Tel: Fax:

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SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-307A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			16											
			17											
			18											
			19											
			20	SILT, dark gray (2.5y, 2.5/1), with trace sand, fine grain to cousrse.	ML									
S1	19	3 1 0 9	21						0.75	W				Took two jar samples at 20-22' bgs.
			22											
			23											
			24											
			25	Same										
				POORLY GRADED SAND, fine to medium grain, trace coarse grain, dark gray (2.5y, 2.5/1).	SP									
S2	14	5 7 9 11	26							W				Roberts began pumping water down hole to keep sand out of augers.
			27											
			28											
			29											
			30	Same, trace silt.										
S3	8	3 6 7 7	31							W				
			32											
			33											
			34											
			35	Same, fine to medium grain, grayish brown (2.5y, 3/1), trace pieces of gravel, no silt.										
S4	8	3 5 7 8	36							W				
			37											
			38											
			39											
			40											

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-307A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
S5	22	2 3 6 6	41–44	POORLY GRADED SAND, fine to medium grain, gray (2.5y, 4/1), trace gravel with 6" layer of sticks in middle of spoon.						W				Large amount of sticks in center of spoon.
S6	20	4 6 11 12	45–49	Same, fine to coarse grain, trace gravel, gray to grayish brown (2.5y, 4/1) with trace sticks.						W				
S7	0.5	4 26 16	50–54	Same, no sticks.	SP					W				Refusal last 6 inches, sand pushed up into augers and locked up spoon.
S8	20	4 9 14 19	55–60	Same, fine to medium grain, gray to grayish brown (2.5y, 4/1).						W				Took two jar samples from 55-57' bgs.
				End of boring ar 60' below ground surface. Set well from 59' bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION
Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-308

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/15/2015	12/16/2015	4-1/2 hollow stem auger

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-308	Feet	534.89 Feet	8.5 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,359 N, 2,300,306 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' " Long ° ' "
Local Grid Location Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–1	FILL, boring location was cleared to 5' bgs by hydrovac, then back filled.	FILL									
			5	SANDY SILT, olive brown (2.5Y 4/3).	ML S									
S1	14	22 12 13 15	6							W				
S2	18	2 2 4 8	8–9							W				
S3	18	1 2 2 50	11							W				
S4	14	3 15 50	13–14							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]
Firm: SCS Engineers, 2830 Dairy Drive Madison, WI 53718
Tel: (608) 224-2830
Fax:

This form is authorized by Chapters 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats. Completion of this form is mandatory. Failure to file this form may result in forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on this form is not intended to be be used for any other purpose. NOTE: See instructions for more information, including where the completed form should be sent.

SOIL BORING LOG INFORMATION SUPPLEMENT

Form 4400-122A

Boring Number MW-308 Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
				LEAN CLAY, black (2.5Y 2.5/1).	CL									
S5	12	6 4 2 4	16							W				
			17											
			18											
S6	12	5 6 5 10	19							W				
			20	SILT, very dark gray (7.5YR 3/1), trace sand.	ML									
S7	18	1 1 1 2	21							W				
			22											
			23	POORLY GRADED SAND, very dark gray (2.5Y 3/1), coarse grained.	SP									
S8	10	1 12 13 18	24							W				
			25											
S9	12	2 6 8 10	26							W				
			27											
			28											
S10		2 2 6 8	29							W				
				End of Boring at 29.5 ft bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION

Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-309

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	3/1/2016	3/1/2016	4-1/2 hollow stem auger

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-309	Feet	534.11 Feet	8.5 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,210 N, 2,300,022 E S/C/N
SW 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' "
Long ° ' "
Local Grid Location: Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
			10	LEAN CLAY, olive brown (2.5Y 4/3).										
S1	14		11							W				
			12	Same as above except, gray (2.5Y 6/1).	CL									
S2	34		14							W				
			15											

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: (608) 224-2830 Fax:

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-309 Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
S3	34		16–18	Same as above except, very dark gray (2.5Y 3/1).	CL					W				
S4	31		18–25	POORLY GRADED SAND, coarse grained, very dark gray (10YR 3/1).	SP					W				
			25	End of Boring at 25 feet bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION

Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-310

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	3/1/2016	3/1/2016	Direct Push 4-1/2/HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-310	Feet	532.23 Feet	8.5 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,610 N, 2,298,832 E S/C/N
NE 1/4 of SE 1/4 of Section 30, T 69 N, R 2 W
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location: Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	LEAN CLAY WITH SAND, dark olive brown (2.5Y 3/3).										
S1	13		2							M				
S2	33		6		CL					M				
			7	Same as above except, very dark gray (2.5Y 3/1).										
S3	22		10	Trace organics.						M				
			12	SILTY SAND, very dark grayish brown (2.5Y 3/2).	SM									
			13	POORLY GRADED SAND, coarse grained, very dark grayish brown (2.5Y 3/2).	SP									
S4	31		14							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: (608) 224-2830 Fax:

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-310 Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			16											
			17		SP									
S5	35		18							W				
			19											
				LEAN CLAY, dark gray (2.5Y 4/1).	CL									
			20	POORLY GRADED SAND, very dark grayish brown (2.5Y 3/2).										
			21		SP									
S6	NA		22							W				Sample stuck in discrete sampler. Refusal @24'.
			23	LEAN CLAY, dark gray (2.5Y 4/1), (weathered bedrock).	CL									
			24	End of Boring at 24 feet bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION
Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Burlington Generating Station SCS#: 25220055.00		MW-310A

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Crank Roberts Environmental Services	6/25/2020	6/26/2020	4.25" HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			9.15 Feet	532.91 Feet MSL	8.0 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,610 N, 2,298,832 E S/C/N
NE 1/4 of SE 1/4 of Section 30, T 69 N, R 2 W
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location: Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–15	Blind drilled to 20' below ground surface. See logs for MW-310 for log information between 0-20' bgs.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm
[signature]	SCS Engineers Tel: Fax:

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SOIL BORING LOG INFORMATION SUPPLEMENT

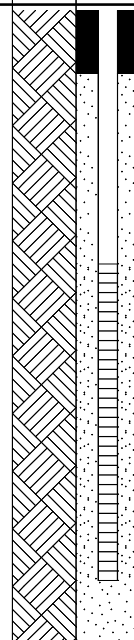
Form 4400-122A

Boring Number MW-310A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			16–19											
S1		0 0 0 0	20–22	LEAN CLAY, gray (5y, 3/2), dense with trace sand and gravel.	CL									Took three jar samples from 20-24' bgs.
S2		4 7 11 9	22–25	POORLY GRADED SAND, fine to medium grain, grayish brown.	SP									
S3			25–30	MUDSTONE (bedrock), 0.25" size pieces and smaller of rock (silt grain size, when broken up), light gray to gray, slightly reactive with acid, with poorly graded sand (overburden), coarse grain, grayish brown.										Bedrock at 25' bgs. Switched to air rotary at 25' bgs.
S4			30–35	MUDSTONE, gray (bedrock). (Feels like clay ounce brocken up) with much less sand.										
S5			35–40	Same, trace sand, sampled intermittently between 35-40' bgs.										

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-310A Use only as an attachment to Form 4400-122.



Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
	S6		41 42 43 44	MUDSTONE, mostly mudstone with some poorly graded sand.										
	S7		45 46 47 48 49	Same, moslty mudstone with more sand and pieces of lean clay, dark gray (most likely overburden).										
	S8		50	End of Boring at 50' below ground surface. Set well at 49' bgs.										Took two jar samples from 47' bgs.

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION

Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-311

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	3/1/2016	3/1/2016	Direct Push 4-1/2/HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-311	Feet	532.69 Feet	8.5 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,439 N, 2,298,835 E S/C/N
NE 1/4 of SE 1/4 of Section 30, T 69 N, R 2 W
Lat ° ' "
Long ° ' "
Local Grid Location: Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	TOPSOIL.	TOPSOIL									
			0–4	LEAN CLAY, dark olive brown (2.5Y 3/3).										
S1	14		2		CL					M				
			4–8	POORLY GRADED SAND, yellowish brown (10YR 5/8), coarse grained.										
S2	8		6		SP					M				
			8–15	LEAN CLAY, very dark gray (2.5Y 3/1).										
S3	6		10							M				Rock in shoe.
			11		CL									
S4	25		14							M				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: (608) 224-2830 Fax:

SOIL BORING LOG INFORMATION SUPPLEMENT

Form 4400-122A

Boring Number MW-311 Use only as an attachment to Form 4400-122.

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
					CL									
S5	34		16–19	SILTY SAND, black (2.5Y 2.5/1).	SM					W				
			19–20	POORLY GRADED SAND, very dark grayish brown (2.5Y 3/2).	SP									
S6	40		20–23	SILTY SAND, very dark grayish brown (2.5Y 3/2).	SM					W				
			23–24	SILT, very dark grayish brown (2.5Y 3/2).	ML									
S7	45		24–28	LEAN CLAY, dark gray (2.5Y 4/1), laminated, organics.	CL					W				
			28–29	POORLY GRADED SAND, very dark grayish brown (2.5Y 3/2).	SP									
S8			29–32	LEAN CLAY, dark gray (2.5Y 4/1), laminated, organics. Same as above except, dark greenish gray (5GY 4/1), shells.	CL					W				
			32	End of Boring at 32 feet bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL - Burlington Generating Station SCS#: 25218220.00		MW312

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Crank Roberts Environmental Drilling	5/20/2019	5/20/2019	4.25" HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW312	531.08 Feet	533.8 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,576 N, 2,300,970 E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			0–8	Hydrovaced to 8'										
	4	3 3 6 7	8–10	LEAN CLAY, teal/blue, (GLEY1 5/10 GY), trace coarse sand	CL					M				
	18	3 4 5 7	10–12	same as above but dark green, (GLEY1 3/10 GY), with gravel.						M				
	10	1 2 5 8	12–14	trace organic material						M				
			14–15	same as above but dark green, (10YR 2/1)										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature] for Zach Watson
Firm: SCS Engineers
2830 Dairy Drive, Madison, WI 53718
Tel:
Fax:

Boring Number MW312

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
	24	1 4 5 6		LEAN CLAY, teal/blue, (GLEY1 5/10 GY), trace coarse sand. *(continued)*	CL					M				
			16											
			17							M				
			18											
		2 3 3 4	19							M				
			20	POORLY GRADED SAND, fine to coarse, (2.5YR 3/2).	SP									
	6	0 1 2 3	21							W				
			22											
	6	1 2 4 5	23							W				
			24											
	4		25							W				
			26	End of Boring at 26 feet.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL - Burlington Generating Station SCS#: 25218220.00		MW313

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Crank Roberts Environmental Drilling	5/21/2019	5/21/2019	4.25" HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW313	531.05 Feet	534.0 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,130 N, 2,300,907 E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location ☐ N Feet ☐ S ☐ E Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–8	Hydrovaced to 8'										
			8	LEAN CLAY, (GLEY1 4/10Y), trace coarse sand	CL									
	8	3 1 4 5	9							M				
	8	1 1 3 4	11							M				
			12	Trace organic material										
	8	1 1 2 2	13							M				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature] for Zach Watson
Firm: SCS Engineers
2830 Dairy Drive, Madison, WI 53718
Tel:
Fax:

Boring Number MW313

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
	12	1 1 2 2		LEAN CLAY, (GLEY1 4/10Y), trace coarse sand. *(continued)*						M				
			16	Same as above but dark gray, (10YR 2/1).										
		1 1 2 2	17							M				
			18											
		1 1 2 2	19							M				
			20		CL									
	18	1 1 3 4	21							M				
			22											
	24	3 2 3 4	23							M				
			24	Small sand lenses.										
	18	1 1 2 8	25							M				
			26	POORLY GRADED SAND, coarse.										
	4		27							W				
			28											
	10	3 2 4 6	29		SP					W				
			30											
	0	1 3 8 7	31							W				
			32	End of Boring at 32 feet.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION
Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Burlington Generating Station SCS#: 25220055.00		MW-313A

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Crank Roberts Environmental Services	6/23/2020	6/30/2020	4.25" HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			12.13 Feet	529.35 Feet MSL	8.0 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,130 N, 2,300,907 E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location
Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			1–15	Blind drilled to 28' below ground surface. See logs for MW-313 for log information between 0-28' bgs.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm
[signature]	SCS Engineers Tel: Fax:

SOIL BORING LOG INFORMATION SUPPLEMENT

Form 4400-122A

Boring Number MW-313A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			16											
			17											
			18											
			19											
			20											
			21											
			22											
			23											
			24											
			25											
			26											
			27											
			28	POORLY GRADED SAND, fine to medium grain, grayish brown.										
S1/S2	12	2 2 6 8	29							W				Took two jar samples from 28-30' bgs. Roberts began pumping water into augers to keep sand from backing up into augers.
			30	Same										
S3	12	5 8 11 12	31							W				
			32	Same, fine to coarse grain, grayish brown, trace gravel and clay.										
S4	14	3 4 5 5	33							W				
			34	Same	SP									
S5	5	1 3 5 6	35							W				Switched to 2' sample every five feet.
			36											
			37											
			38											
			39											
			40											

Boring Number MW-313A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
S6	10	1 6 7 9	41	POORLY GRADED SAND, fine to mostly coarse grain, trace gravel, grayish brown.						W				
			42											
			43											
			44											
S7	12	3 3 8 11	45–46	Same, fine to medium grain, trace coarse grain.						W				
			47											
			48											
			49											
S8	15	3 8 21 15	50–51	Same, fine to coarse grain.	SP					W				
			52											
			53											
			54											
S9	18	1 1 0 1	55–56	Same, mostly fine to medium grain with trace coarse grain and gravel, grayish brown.						W				
			57											
			58											
			59											
S10	16	3 3 6 9	60–61	Same fine to coarse grain, grayish brown.						W				Took two jar samples from 55-57' bgs and 60-62' bgs and combined them
			62	End of boring at 62' below ground surface. Set well at 61' bgs.										

Print Form

IOWA DEPARTMENT OF NATURAL RESOURCES

MONITORING WELL/PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL - Burlington Generating Station Permit No.:

Well or Piezometer No: MW-301

Dates Started: 2/29/16 Date Completed: 2/29/16

A. SURVEYED LOCATIONS AND ELEVATIONS

Locations (± 0.5 ft):

Specify corner of site: SE of Parcel 16-29-300-007

Distance & direction along boundary: 119' W

Distance & direction from boundary to wall: 356' N

Elevations (± 0.01 ft MSL):

Ground Surface: 535.98

Top of protective casing: 538.75

Top of well casing: 538.38

Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Name & Address of Construction Company:

Direct Push Analytical Corp

4N969 Old LaFox Road, Unit E

St. Charles, IL 60175

Name of Driller: Kevin Collins

Drilling Method: Direct Push/4.25" HSA

Drilling Fluid: NA

Bore Hole Diameter: 8.5 inch

Soil Sampling Method: Macro Core

Depth of Boring: 29.50 ft bgs

C. MONITORING WELL INSTALLATION

Casing material: PVC

Length of casing: 24.5

Outside casing diameter: 2.38"

Inside casing diameter: 2"

Casing joint type: threaded

Casing/screen joint type: threaded

Screen material: PVC

Screen opening size: 0.010"

Screen length: 5 ft

Depth of well: 29.5 ft

Filter Pack:

Material: NSF R.W Sidley Inc.

Grain size: 10/20

Volume: 2.25 cubic ft

Seal (minimum 3 ft length above filter pack):

Material: Black Hills Bentonite 3/8 inch

Placement method: Gravity

Volume: 4.4 cubic ft

Backfill (if different from seal):

Material:

Placement method:

Volume:

Surface seal design:

Material of protective casing: Steel 4 inch

Material of grout between protective casing and well casing: sand

Protective cap:

Material: Steel, vented

Vented: ☐ Yes ☐ No Locking: ☒ Yes ☐ No

Well Cap:

Material: PVC

Vented: ☐ Yes ☒ No

D. GROUNDWATER MEASURMENT (± 0.01 ft below top of inner well casing)

Water level: 15.47 ft Stabilization Time: <5 minutes

Well development method: Surged with block and pumped to reduce turbidity. 45 gallons pumped.

Average depth of frostline: 3.5'

Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½x11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed for to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E 9th St, Des Moines IA 50319-0034.

Questions? Call or Email: Nina Koger, Environmental Engineer Sr., 515-281-8986, Nina.Koger@dnr.iowa.gov

ELEVATIONS: ± 0.01 ft MSL
DEPTHS: ± 0.1 ft FROM GROUND SURFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL.)

TOP OF PROTECTIVE CASING
ELEVATION 538.75

TOP OF WELL CASING
ELEVATION 538.38

GROUND SURFACE
ELEVATION 535.98

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 533.98
DEPTH 2

BASE OF PROTECTIVE CASING
ELEVATION 533.48
DEPTH 2.5

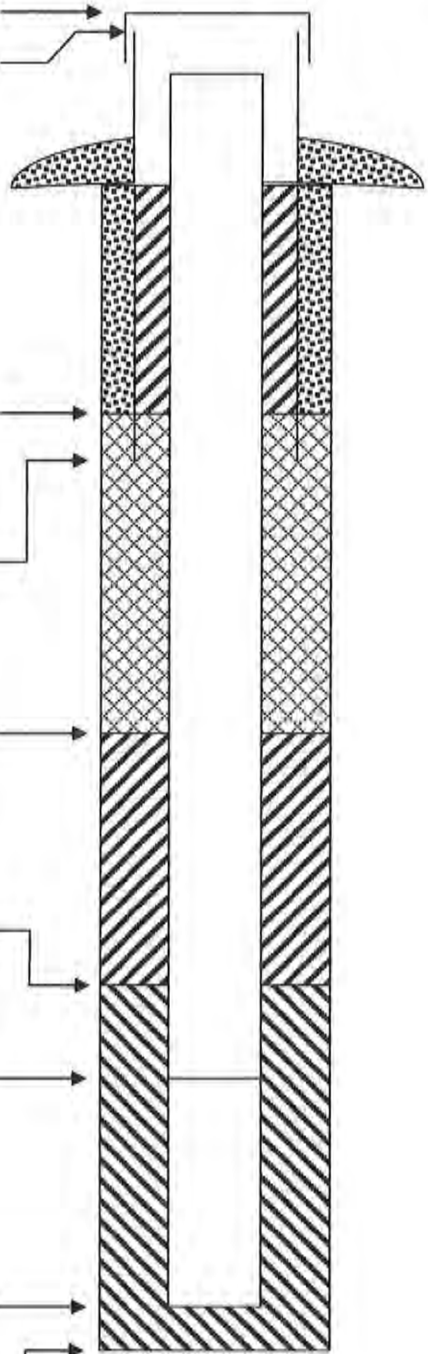
BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 513.48
DEPTH 22.5

TOP OF SCREEN
ELEVATION 511.48
DEPTH 24.5

BOTTOM OF SCREEN
ELEVATION 506.48
DEPTH 29.5

BASE OF FILTER PACK
ELEVATION 506.48
DEPTH 29.5



Print Form

IOWA DEPARTMENT OF NATURAL RESOURCES

MONITORING WELL/PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL - Burlington Generating Station   Permit No.:

Well or Piezometer No: MW-302

Dates Started: 2/29/16   Date Completed: 2/29/16

A. SURVEYED LOCATIONS AND ELEVATIONS

Locations (± 0.5 ft):

Specify corner of site: SE of Parcel 16-29-300-008

Distance & direction along boundary: 315' W

Distance & direction from boundary to wall: 34'N

Elevations (± 0.01 ft MSL):

Ground Surface: 533.24

Top of protective casing: 535.98

Top of well casing: 535.69

Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Name & Address of Construction Company:

Direct Push Analytical Corp

4N969 Old LaFox Road, Unit E

St. Charles, IL 60175

Name of Driller: Kevin Collins

Drilling Method: Direct Push/4.25" HSA

Drilling Fluid: NA

Bore Hole Diameter: 8.5 inch

Soil Sampling Method: Macro Core

Depth of Boring: 28 ft bgs

C. MONITORING WELL INSTALLATION

Casing material: PVC

Length of casing: 22.5

Outside casing diameter: 2.38"

Inside casing diameter: 2"

Casing joint type: threaded

Casing/screen joint type: threaded

Screen material: PVC

Screen opening size: 0.010"

Screen length: 5 ft

Depth of well: 27.5

Filter Pack:

Material: NSF R.W Sidley Inc.

Grain size: 10/20

Volume: 1.25 cubic ft

Seal (minimum 3 ft length above filter pack):

Material: Black Hills Bentonite 3/8 inch

Placement method: Gravity

Volume: 2.7 cubic ft

Backfill (if different from seal):

Material:

Placement method:

Volume:

Surface seal design:

Material of protective casing: Steel 4 inch

Material of grout between protective casing and well casing: sand

Protective cap:

Material: Steel, vented

Vented: ☒ Yes ☐ No   Locking: ☐ Yes ☐ No

Well Cap:

Material: PVC

Vented: ☐ Yes ☒ No

D. GROUNDWATER MEASURMENT (± 0.01 ft below top of inner well casing)

Water level: 12.70 ft   Stabilization Time: <5 minutes

Well development method: Surged with block and pumped to reduce turbidity. 68.5 gallons pumped.

Average depth of frostline: 3.5

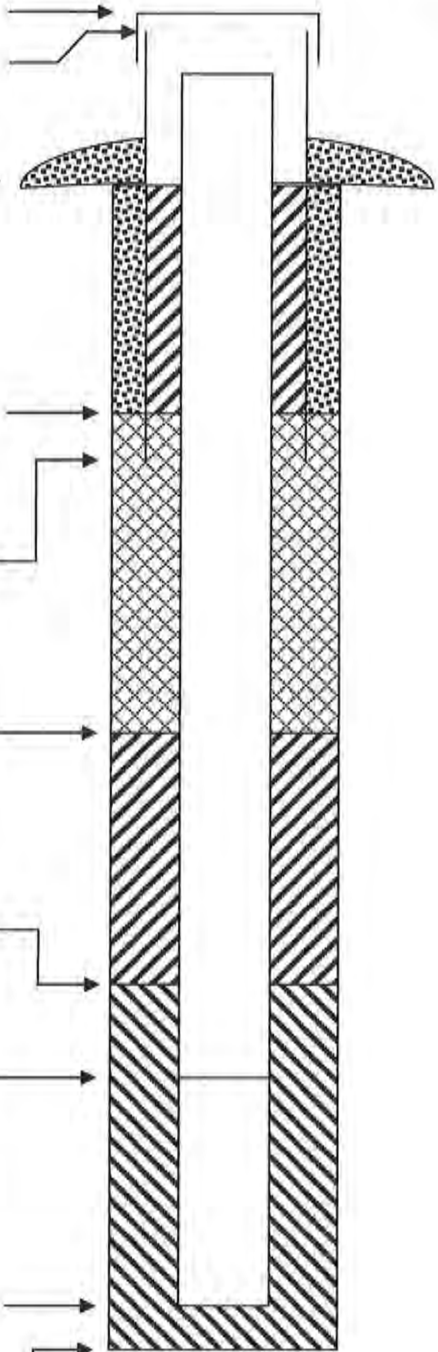
Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½x11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed for to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E 9th St, Des Moines IA 50319-0034.

Questions? Call or Email: Nina Koger, Environmental Engineer Sr., 515-281-8986, Nina.Koger@dnr.iowa.gov

ELEVATIONS: ± 0.01 ft MSL
DEPTHS: ± 0.1 ft FROM GROUND SURFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL.)



TOP OF PROTECTIVE CASING
ELEVATION 535.98

TOP OF WELL CASING
ELEVATION 535.69

GROUND SURFACE
ELEVATION 533.24

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 532.24
DEPTH 1.0

BASE OF PROTECTIVE CASING
ELEVATION 530.74
DEPTH 2.5

BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 512.74
DEPTH 20.5

TOP OF SCREEN
ELEVATION 510.74
DEPTH 22.5

BOTTOM OF SCREEN
ELEVATION 505.74
DEPTH 27.5

BASE OF FILTER PACK
ELEVATION 504.24
DEPTH 28

MONITORING WELL / PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: Burlington Generating Station — Permit No.:
Well or Piezometer No.: MW-302A — Dates Started: 6/30/2020 — Date Completed: 7/1/2020

A. SURVEYED LOCATION AND ELEVATION OF POINT (+0.5 ft.)

Specify corner of site: South East Corner — Distance and direction along boundary:
Distance and direction from boundary to surface monitoring well:
Elevation (+0.01 ft. MSL):
Ground Surface: 533.51' — Top of protective casing: 536.28'
Top of well casing: 535.89' — Benchmark elevation:
Benchmark description:

B. SOIL BORING INFORMATION

Construction Company Name: Roberts Environmental Drilling
Address: 1107 S Mulberry St — City, State, Zip Code: Millstadt, IL 62260
Name of driller: Jeff Crank
Drilling method: Hollow Stem Auger — Drilling fluid: Water — Bore Hole diameter: 4.25"
Soil sampling method: Split spoon — Depth of boring: 61'

C. MONITORING WELL INSTALLATION

Casing material: Sch. 40 PVC
Length of casing: 62.5'
Outside casing diameter: 2.4"
Inside casing diameter: 2"
Casing joint type: Threaded
Casing/screen joint type: Threaded
Screen material: Sch. 40 PVC
Screen opening size: 0.01
Screen length: 5'
Depth of Well: 60'
Filter Pack:
- Material: Sand (FilterSil)
- Grain Size: 18-23
- Volume: 2, 50lbs bags

Seal (minimum 3 ft. length above filter pack):
- Material: Bentonite grout
- Placement method: Pumped
- Volume: 8, 50lbs bags (120 gallons of grout)

Backfill (if different from seal):
- Material: 3/8" Bentonite chips
- Placement method: Poured
- Volume: 3, 50lbs bags

Surface seal design: Stick-up
- Material of protective casing: steel
- Material of grout between protective casing and well casing: Sand

Protective cap:
- Material: Steel
- Vented?: ☒ Y ☐ N — Locking?: ☒ Y ☐ N

Well cap: Lockable expanding well plug
- Material: Plastic
- Vented?: ☐ Y ☒ N

D. GROUNDWATER MEASUREMENT (±0.01 foot below top of inner well casing)

Water level 14.25' — **Stabilization time** < 5 min
Well development method Surged with bailer and pumped
Average depth of frost line 4'

DRILLER'S CERTIFICATION

I certify under penalty of law I believe the information reported above is true, accurate, and complete.

Signature Jeff Crank — **Certification #** 8515 — **Date** 9-16-20

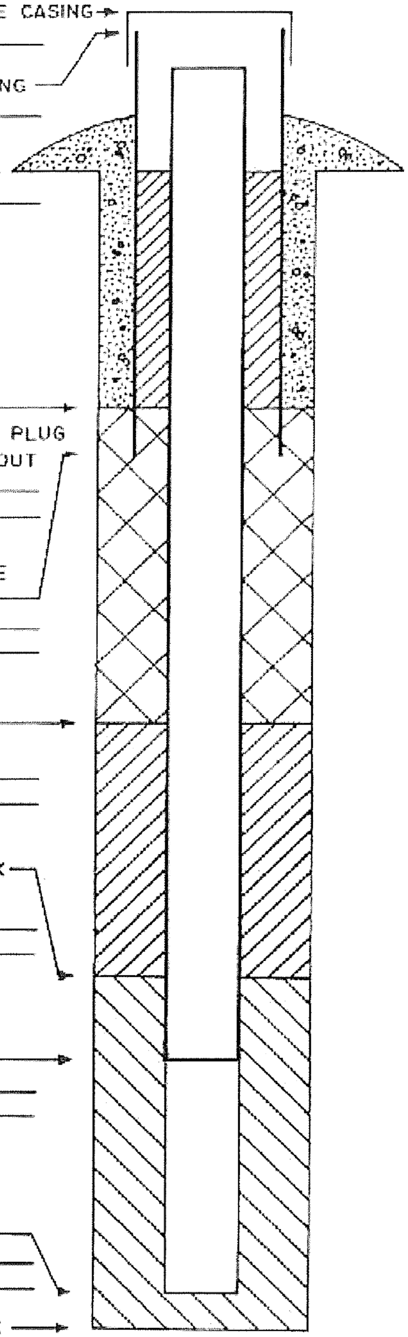
Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½ inch x 11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed form to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E. 9th St, Des Moines, IA 50319.
Questions? Call or Email: Nina Booker Environmental Engineer Sr., 515-725-8309, nina.booker@dnr.iowa.gov

ELEVATIONS: ± 0.01 FT. MSL

DEPTHS: ± 0.1 FT. FROM GROUND SERFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL).



TOP OF PROTECTIVE CASING
ELEVATION 536.28

TOP OF WELL CASING
ELEVATION 535.89

GROUND SURFACE
ELEVATION 533.51

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION
DEPTH 4.5'

BASE OF PROTECTIVE
CASING
ELEVATION
DEPTH 4.5'

BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH 52'

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION
DEPTH 52'

TOP OF SCREEN
ELEVATION 55'
DEPTH 55'

BOTTOM OF SCREEN
ELEVATION
DEPTH 60'

BASE OF FILTER PACK
ELEVATION
DEPTH 61'

Print Form

IOWA DEPARTMENT OF NATURAL RESOURCES

MONITORING WELL/PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL - Burlington Generating Station Permit No.:

Well or Piezometer No: MW-303

Dates Started: 12/15/15 Date Completed: 12/15/15

A. SURVEYED LOCATIONS AND ELEVATIONS

Locations (± 0.5 ft):

Specify corner of site: SE of Parcel 16-29-300-008

Distance & direction along boundary: 89' W

Distance & direction from boundary to wall: 139' N

Elevations (± 0.01 ft MSL):

Ground Surface: 531.01

Top of protective casing: 534.08

Top of well casing: 533.6

Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Name & Address of Construction Company:

Cascade Drilling, LP

301 Alderson St

Schofield, WI 54476

Name of Driller: Mike Mueller

Drilling Method: 4.25" HSA

Drilling Fluid: NA

Bore Hole Diameter: 8.5 inch

Soil Sampling Method: Spoon

Depth of Boring: 27 ft

C. MONITORING WELL INSTALLATION

Casing material: PVC

Length of casing: 21 ft

Outside casing diameter: 2.38"

Inside casing diameter: 2"

Casing joint type: threaded

Casing/screen joint type: threaded

Screen material: PVC

Screen opening size: 0.010"

Screen length: 5 ft

Depth of well: 26 ft

Filter Pack:

Material: Red Flint

Grain size: #40

Volume: 2.5 cubic ft

Seal (minimum 3 ft length above filter pack):

Material: Hole Plug 3/8 inch

Placement method: Gravity

Volume: 7.4 cubic ft

Backfill (if different from seal):

Material:

Placement method:

Volume:

Surface seal design:

Material of protective casing: Steel 6 inch

Material of grout between protective casing and well casing: sand

Protective cap:

Material: steel, vented

Vented: ☐ Yes ☐ No Locking: ☒ Yes ☐ No

Well Cap:

Material: PVC

Vented: ☐ Yes ☒ No

D. GROUNDWATER MEASURMENT (± 0.01 ft below top of inner well casing)

Water level: 10.55 ft Stabilization Time: <5 minutes

Well development method: Surged with block and pumped to reduce turbidity. 147 gallons pumped.

Average depth of frostline: 3.5'

Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½x11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed for to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E 9th St, Des Moines IA 50319-0034.

Questions? Call or Email: Nina Koger, Environmental Engineer Sr., 515-281-8986, Nina.Koger@dnr.iowa.gov

ELEVATIONS: ± 0.01 ft MSL
DEPTHS: ± 0.1 ft FROM GROUND SURFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL.)

TOP OF PROTECTIVE CASING
ELEVATION 534.08

TOP OF WELL CASING
ELEVATION 533.6

GROUND SURFACE
ELEVATION 531.01

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 529.01
DEPTH 2.0

BASE OF PROTECTIVE CASING
ELEVATION 528.51
DEPTH 2.5

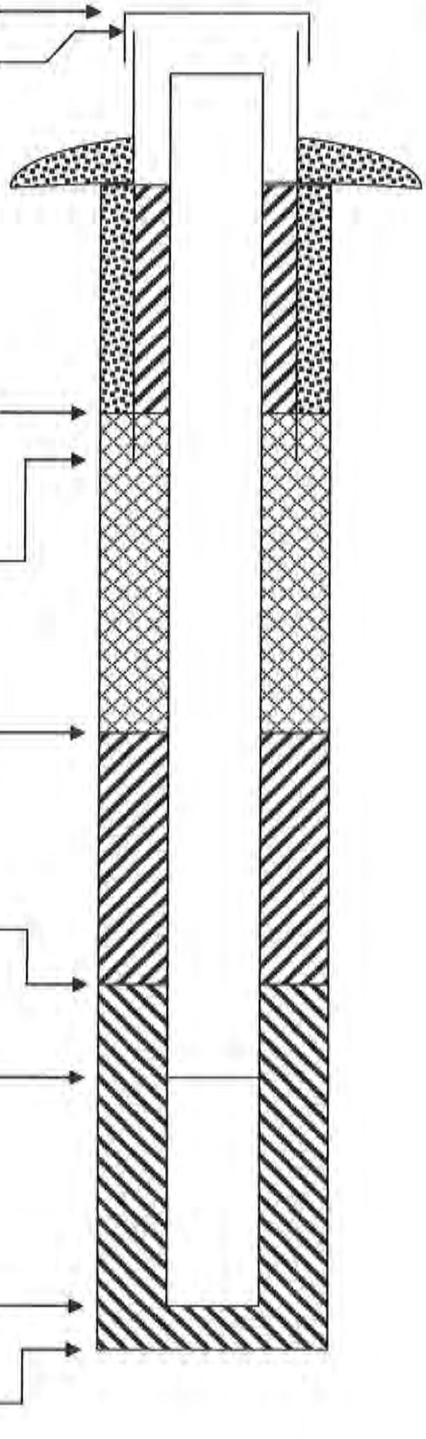
BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 511.51
DEPTH 19.5

TOP OF SCREEN
ELEVATION 510.01
DEPTH 21

BOTTOM OF SCREEN
ELEVATION 505.01
DEPTH 26

BASE OF FILTER PACK
ELEVATION 503.51
DEPTH 27.5



Print Form

IOWA DEPARTMENT OF NATURAL RESOURCES

MONITORING WELL/PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL - Burlington Generating Station   Permit No.:

Well or Piezometer No: MW-304

Dates Started: 12/15/15   Date Completed: 12/15/15

A. SURVEYED LOCATIONS AND ELEVATIONS	**B. SOIL BORING INFORMATION**
Locations (± 0.5 ft):	Name & Address of Construction Company:
Specify corner of site: SE of Parcel 16-29-300-008	Cascade Drilling, LP
Distance & direction along boundary: 61' W	301 Alderson St
Distance & direction from boundary to wall: 558' N	Schofield, WI 54476
Elevations (± 0.01 ft MSL):	Name of Driller: Mike Mueller
Ground Surface: 532.15	Drilling Method: 4.25" HSA
Top of protective casing: 535.00	Drilling Fluid: NA
Top of well casing: 534.42	Bore Hole Diameter: 8.5 inch
Benchmark elevation:	Soil Sampling Method: Spoon
Benchmark description:	Depth of Boring: 27 ft

C. MONITORING WELL INSTALLATION

Casing material: PVC	Placement method: Gravity
Length of casing: 18 ft	Volume: 4 cubic ft
Outside casing diameter: 2.38"	Backfill (if different from seal):
Inside casing diameter: 2"	Material:
Casing joint type: threaded	Placement method:
Casing/screen joint type: threaded	Volume:
Screen material: PVC	Surface seal design:
Screen opening size: 0.010"	Material of protective casing: Steel 6 inch
Screen length: 5 ft	Material of grout between protective casing and well casing: sand
Depth of well: 23 ft	Protective cap:
Filter Pack:	Material: steel, vented
Material: Red Flint	Vented: ☐ Yes ☐ No Locking: ☒ Yes ☐ No
Grain size: #40	Well Cap:
Volume: 2.0 cubic ft	Material: PVC
Seal (minimum 3 ft length above filter pack):	Vented: ☐ Yes ☒ No

Material: Hole Plug 3/8 inch

D. GROUNDWATER MEASURMENT (± 0.01 ft below top of inner well casing)

Water level: 11.34 ft   Stabilization Time: <5 minutes

Well development method: Surged with block and pumped to reduce turbidity. 136 gallons pumped.

Average depth of frostline: 3.5'

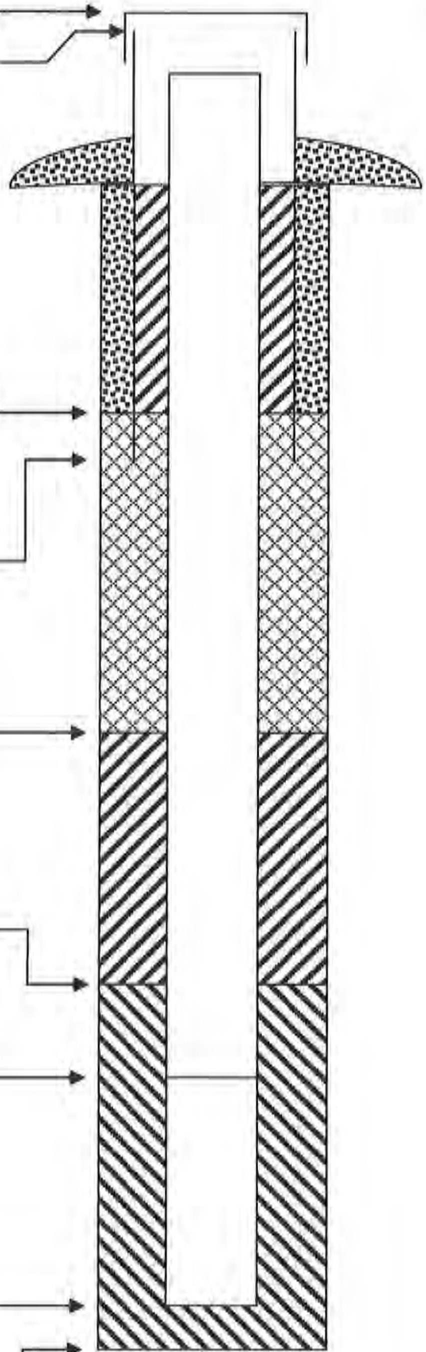
Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½x11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed for to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E 9th St, Des Moines IA 50319-0034.

Questions? Call or Email: Nina Koger, Environmental Engineer Sr., 515-281-8986, Nina.Koger@dnr.iowa.gov

ELEVATIONS: ± 0.01 ft MSL
DEPTHS: ± 0.1 ft FROM GROUND SURFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL.)



TOP OF PROTECTIVE CASING
ELEVATION 535
TOP OF WELL CASING
ELEVATION 534.42

GROUND SURFACE
ELEVATION 532.15

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 529.15
DEPTH 3

BASE OF PROTECTIVE CASING
ELEVATION 529.65
DEPTH 2.5

BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 515.65
DEPTH 16.5

TOP OF SCREEN
ELEVATION 514.15
DEPTH 18

BOTTOM OF SCREEN
ELEVATION 509.15
DEPTH 23

BASE OF FILTER PACK
ELEVATION 505.15
DEPTH 27

Print Form

IOWA DEPARTMENT OF NATURAL RESOURCES

MONITORING WELL/PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL - Burlington Generating Station Permit No.:

Well or Piezometer No: MW-305

Dates Started: 12/17/15 Date Completed: 12/17/15

A. SURVEYED LOCATIONS AND ELEVATIONS

Locations (± 0.5 ft):

Specify corner of site: NW of Parcel 16-29-300-006

Distance & direction along boundary: 475' S

Distance & direction from boundary to wall: 297' E

Elevations (± 0.01 ft MSL):

Ground Surface: 530.85

Top of protective casing: 533.93

Top of well casing: 533.28

Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Name & Address of Construction Company:

Cascade Drilling, LP

301 Alderson St

Schofield, WI 54476

Name of Driller: Mike Mueller

Drilling Method: 4.25" HSA

Drilling Fluid: NA

Bore Hole Diameter: 8.5 inch

Soil Sampling Method: Spoon

Depth of Boring: 27.5 ft

C. MONITORING WELL INSTALLATION

Casing material: PVC

Length of casing:

Outside casing diameter: 2.38"

Inside casing diameter: 2"

Casing joint type: threaded

Casing/screen joint type: threaded

Screen material: PVC

Screen opening size: 0.010"

Screen length: 5

Depth of well: 32

Filter Pack:

Material: Red Flint

Grain size: #40

Volume: 2.0 cubic ft

Seal (minimum 3 ft length above filter pack):

Material: Hole Plug 3/8 inch

Placement method: Gravity

Volume: 5.4 cubic ft

Backfill (if different from seal):

Material:

Placement method:

Volume:

Surface seal design:

Material of protective casing: Steel 6 inch

Material of grout between protective casing and well casing: sand

Protective cap:

Material: Steel, vented

Vented: ☐ Yes ☐ No Locking: ☒ Yes ☐ No

Well Cap:

Material: PVC

Vented: ☐ Yes ☒ No

D. GROUNDWATER MEASURMENT (± 0.01 ft below top of inner well casing)

Water level: 10.04 ft Stabilization Time: <5 minutes

Well development method: Surged with block and pumped to reduce turbidity. 184 gallons pumped.

Average depth of frostline: 3.5'

Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½x11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed for to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E 9th St, Des Moines IA 50319-0034.

Questions? Call or Email: Nina Koger, Environmental Engineer Sr., 515-281-8986, Nina.Koger@dnr.iowa.gov

ELEVATIONS: ± 0.01 ft MSL
DEPTHS: ± 0.1 ft FROM GROUND SURFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL.)

TOP OF PROTECTIVE CASING
ELEVATION 533.93

TOP OF WELL CASING
ELEVATION 533.28

GROUND SURFACE
ELEVATION 530.85

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 528.85
DEPTH 2.0

BASE OF PROTECTIVE CASING
ELEVATION 528.35
DEPTH 2.5

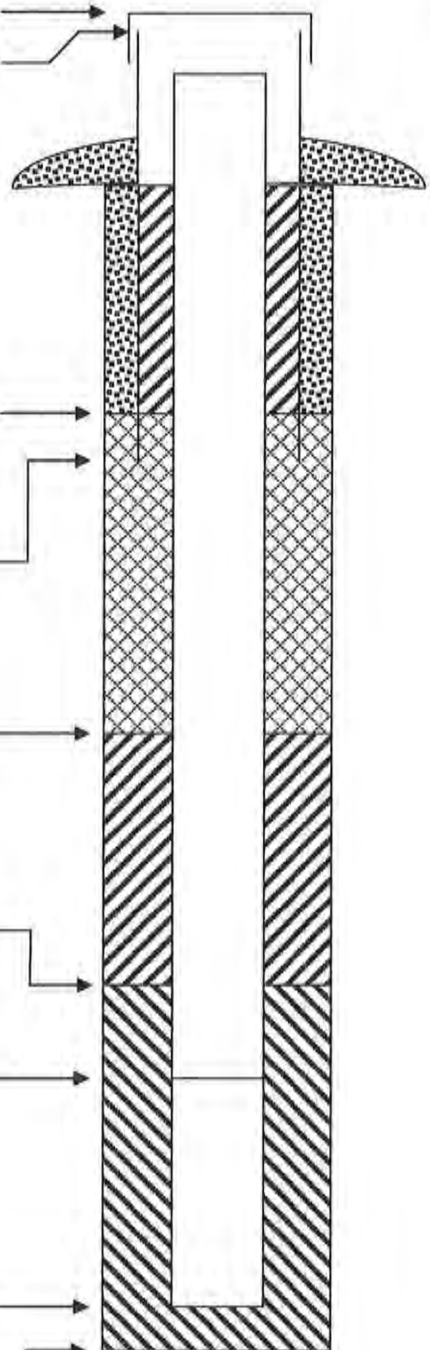
BASE OF BACKFILL
TOP OF SEAL
ELEVATION ______
DEPTH ______

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 510.85
DEPTH 20

TOP OF SCREEN
ELEVATION 508.85
DEPTH 22

BOTTOM OF SCREEN
ELEVATION 503.85
DEPTH 27

BASE OF FILTER PACK
ELEVATION 503.35
DEPTH 27.5



Print Form

IOWA DEPARTMENT OF NATURAL RESOURCES

MONITORING WELL/PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL - Burlington Generating Station Permit No.:

Well or Piezometer No: MW-306

Dates Started: 12/16/15 Date Completed: 12/17/15

A. SURVEYED LOCATIONS AND ELEVATIONS

Locations (± 0.5 ft):

Specify corner of site: SW of Parcel 16-29-300-006

Distance & direction along boundary: 328' N

Distance & direction from boundary to wall: 210' E

Elevations (± 0.01 ft MSL):

Ground Surface: 534.51

Top of protective casing: 537.44

Top of well casing: 536.92

Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Name & Address of Construction Company:

Cascade Drilling, LP

301 Alderson St

Schofield, WI 54476

Name of Driller: Mike Mueller

Drilling Method: 4.25" HSA

Drilling Fluid: NA

Bore Hole Diameter: 8.5 inch

Soil Sampling Method: Spoon

Depth of Boring: 32.5 ft

C. MONITORING WELL INSTALLATION

Casing material: PVC

Length of casing: 27 ft

Outside casing diameter: 2.38"

Inside casing diameter: 2"

Casing joint type: threaded

Casing/screen joint type: threaded

Screen material: PVC

Screen opening size: 0.010"

Screen length: 5 ft

Depth of well: 32 ft

Filter Pack:

Material: Red Flint

Grain size: #40

Volume: 2.5 cubic ft

Seal (minimum 3 ft length above filter pack):

Material: Hole Plug 3/8 inch

Placement method: Gravity

Volume: 6.7 cubic ft.

Backfill (if different from seal):

Material:

Placement method:

Volume:

Surface seal design:

Material of protective casing: Steel 6 inch

Material of grout between protective casing and well casing: sand

Protective cap:

Material: Steel, vented

Vented: ☐ Yes ☐ No Locking: ☒ Yes ☐ No

Well Cap:

Material: PVC

Vented: ☐ Yes ☒ No

D. GROUNDWATER MEASURMENT (± 0.01 ft below top of inner well casing)

Water level: 13.65 Stabilization Time: <5 minutes

Well development method: Surged with block and pumped to reduce turbidity. 120 gallons pumped.

Average depth of frostline: 3.5

Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½x11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed for to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E 9th St, Des Moines IA 50319-0034.

Questions? Call or Email: Nina Koger, Environmental Engineer Sr., 515-281-8986, Nina.Koger@dnr.iowa.gov

ELEVATIONS: ± 0.01 ft MSL
DEPTHS: ± 0.1 ft FROM GROUND SURFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL.)

TOP OF PROTECTIVE CASING
ELEVATION 537.44

TOP OF WELL CASING
ELEVATION 536.92

GROUND SURFACE
ELEVATION 534.51

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 532.51
DEPTH 2.0

BASE OF PROTECTIVE CASING
ELEVATION 532.01
DEPTH 2.5

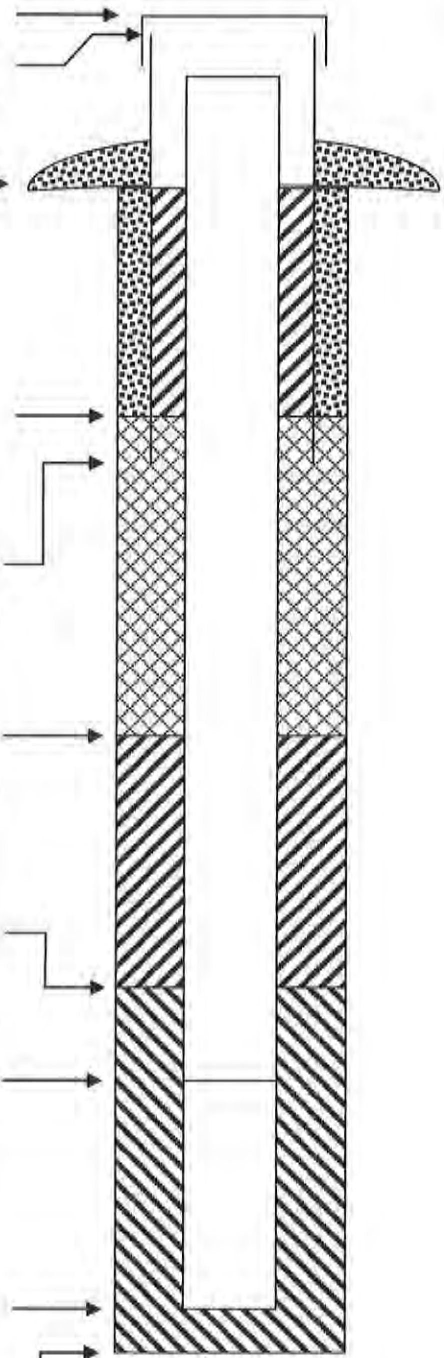
BASE OF BACKFILL
TOP OF SEAL
ELEVATION ______
DEPTH ______

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 509.51
DEPTH 25

TOP OF SCREEN
ELEVATION 507.51
DEPTH 27

BOTTOM OF SCREEN
ELEVATION 502.51
DEPTH 32

BASE OF FILTER PACK
ELEVATION 500.51
DEPTH 34



Print Form

IOWA DEPARTMENT OF NATURAL RESOURCES
MONITORING WELL/PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL - Burlington Generating Station   Permit No.:

Well or Piezometer No: MW-307

Dates Started: 12/16/15   Date Completed: 12/16/15

A. SURVEYED LOCATIONS AND ELEVATIONS		B. SOIL BORING INFORMATION	
Locations (± 0.5 ft):		Name & Address of Construction Company:	
Specify corner of site:	SW of Parcel 16-29-300-006		Cascade Drilling, LP
Distance & direction along boundary:	201' N		301 Alderson St
Distance & direction from boundary to wall:	177' E		Schofield, WI 54476
Elevations (± 0.01 ft MSL):		Name of Driller:	Mike Mueller
Ground Surface:	534.32	Drilling Method:	4.25" HSA
Top of protective casing:	537.54	Drilling Fluid:	NA
Top of well casing:	536.96	Bore Hole Diameter:	8.5 inch
Benchmark elevation:		Soil Sampling Method:	Spoon
Benchmark description:		Depth of Boring:	27 ft

C. MONITORING WELL INSTALLATION

Casing material:	PVC	Placement method:	Gravity
Length of casing:	21 ft	Volume:	6 cubic ft.
Outside casing diameter:	2.38"	Backfill (if different from seal):	
Inside casing diameter:	2"	Material:	
Casing joint type:	threaded	Placement method:	
Casing/screen joint type:	threaded	Volume:	
Screen material:	PVC	Surface seal design:	
Screen opening size:	0.010"	Material of protective casing:	Steel 6 inch
Screen length:	5 ft	Material of grout between protective casing and well casing:	sand
Depth of well:	27 ft	Protective cap:	
Filter Pack:		Material:	Steel, vented
Material:	Red Flint	Vented: ☐ Yes ☐ No	Locking: ☒ Yes ☐ No
Grain size:	#40	Well Cap:	
Volume:	2 cubic ft	Material:	PVC
Seal (minimum 3 ft length above filter pack):		Vented: ☐ Yes ☒ No	
Material:	Hole Plug 3/8 inch		

D. GROUNDWATER MEASURMENT (± 0.01 ft below top of inner well casing)

Water level: 13.34 ft   Stabilization Time: <5 minutes

Well development method: Surged with block and pumped to reduce turbidity. 137 gallons pumped.

Average depth of frostline: 3.5'

Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½x11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed for to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E 9th St, Des Moines IA 50319-0034.

Questions? Call or Email: Nina Koger, Environmental Engineer Sr., 515-281-8986, Nina.Koger@dnr.iowa.gov

ELEVATIONS: ± 0.01 ft MSL
DEPTHS: ± 0.1 ft FROM GROUND SURFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL.)

TOP OF PROTECTIVE CASING
ELEVATION 537.54

TOP OF WELL CASING
ELEVATION 536.96

GROUND SURFACE
ELEVATION 534.32

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 532.32
DEPTH 2.0

BASE OF PROTECTIVE CASING
ELEVATION 531.82
DEPTH 2.5

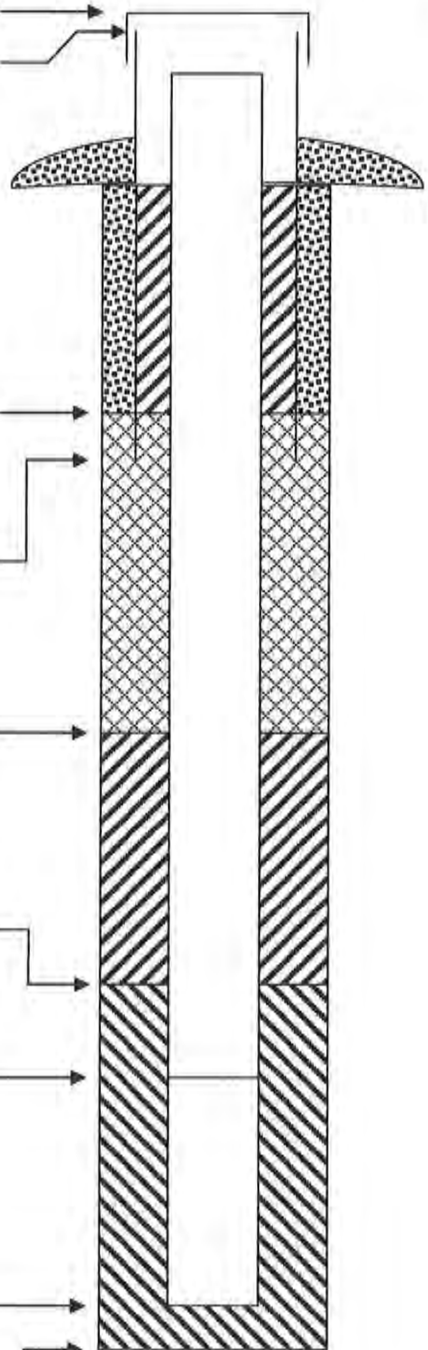
BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 515.32
DEPTH 19

TOP OF SCREEN
ELEVATION 513.32
DEPTH 21

BOTTOM OF SCREEN
ELEVATION 508.32
DEPTH 26

BASE OF FILTER PACK
ELEVATION 507.32
DEPTH 27



MONITORING WELL / PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: Burlington Generating Station   Permit No.:

Well or Piezometer No.: MW-307A   Dates Started: 6/24/2020   Date Completed: 7/1/2020

A. SURVEYED LOCATION AND ELEVATION OF POINT (+0.5 ft.)

Specify corner of site: SW of Parcel 16-29-300-00   Distance and direction along boundary: 201' N

Distance and direction from boundary to surface monitoring well: 177' E

Elevation (+0.01 ft. MSL):

Ground Surface: 533.94'   Top of protective casing: 536.67'

Top of well casing: 536.22'   Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Construction Company Name: Roberts Environmental Drilling

Address: 1107 S Mulberry St   City, State, Zip Code: Millstadt, IL 62260

Name of driller: Jeff Crank

Drilling method: Hollow Stem Auger   Drilling fluid: Water   Bore Hole diameter: 4.25"

Soil sampling method: Split spoon   Depth of boring: 60'

C. MONITORING WELL INSTALLATION

Casing material: Sch. 40 PVC   Placement method: Pumped

Length of casing: 61.92'   Volume: 7, 50lbs bags (~115 gallons of grout)

Outside casing diameter: 2.4"   Backfill (if different from seal):

Inside casing diameter: 2"   Material: 3/8" Bentonite chips

Casing joint type: Threaded   Placement method: Poured

Casing/screen joint type: Threaded   Volume: 5, 50lbs bags

Screen material: Sch. 40 PVC   Surface seal design: Stick-up

Screen opening size: 0.01   Material of protective casing: steel

Screen length: 5'   Material of grout between protective casing and well casing: Sand

Depth of Well: 59'   Protective cap:

Filter Pack: Material: Steel

Material: Sand (FilterSil)   Vented?: ☒ Y ☐ N   Locking?: ☒ Y ☐ N

Grain Size: 18-23   Well cap: Lockable expanding well plug

Volume: 3, 50lbs bags   Material: Plastic

Seal (minimum 3 ft. length above filter pack):   Vented?: ☐ Y ☒ N

Material: Bentonite grout

D. GROUNDWATER MEASUREMENT (±0.01 foot below top of inner well casing)

Water level 14.37'   **Stabilization time** <5 min

Well development method Surged with bailer and pumped

Average depth of frost line 4'

DRILLER'S CERTIFICATION

I certify under penalty of law I believe the information reported above is true, accurate, and complete.

Signature [signature]   **Certification #** 8515   **Date** 9-16-20

Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½ inch x 11 inch map showing locations of all monitoring wells and piezometers.

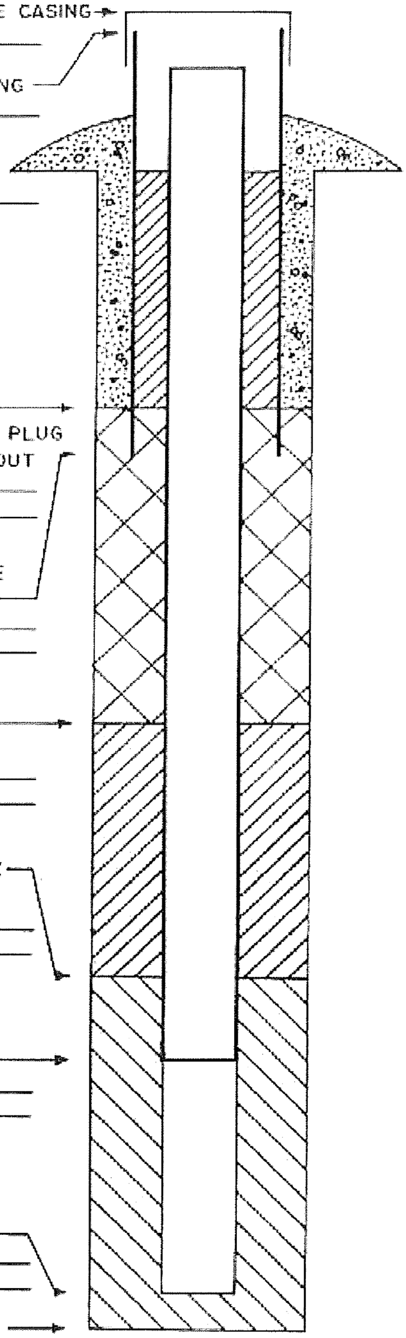
Please mail completed form to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E. 9th St, Des Moines, IA 50319.
Questions? Call or Email: Nina Booker Environmental Engineer Sr., 515-725-8309, nina.booker@dnr.iowa.gov

09/2017 cmc   DNR Form 542-1277

ELEVATIONS: ± 0.01 FT. MSL

DEPTHS: ± 0.1 FT. FROM GROUND SERFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL).



TOP OF PROTECTIVE CASING
ELEVATION 536.67

TOP OF WELL CASING
ELEVATION 536.22

GROUND SURFACE
ELEVATION 533.94

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION
DEPTH 4.5'

BASE OF PROTECTIVE
CASING
ELEVATION
DEPTH 4.5'

BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH 51'

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION
DEPTH 51'

TOP OF SCREEN
ELEVATION 54'
DEPTH 54'

BOTTOM OF SCREEN
ELEVATION
DEPTH 59'

BASE OF FILTER PACK
ELEVATION
DEPTH 60'

Print Form

IOWA DEPARTMENT OF NATURAL RESOURCES

MONITORING WELL/PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL - Burlington Generating Station Permit No.:

Well or Piezometer No: MW-308

Dates Started: 12/15/15 Date Completed: 12/16/15

A. SURVEYED LOCATIONS AND ELEVATIONS

Locations (± 0.5 ft):

Specify corner of site: SW of Parcel 16-29-300-006

Distance & direction along boundary: 33' N

Distance & direction from boundary to wall: 130' E

Elevations (± 0.01 ft MSL):

Ground Surface: 534.89

Top of protective casing: 537.74

Top of well casing: 537.20

Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Name & Address of Construction Company:

Cascade Drilling, LP

301 Alderson St

Schofield, WI 54476

Name of Driller: Mike Mueller

Drilling Method: 4.25" HSA

Drilling Fluid: NA

Bore Hole Diameter: 8.5 inch

Soil Sampling Method: Spoon

Depth of Boring: 29.5 ft

C. MONITORING WELL INSTALLATION

Casing material: PVC

Length of casing: 23 ft

Outside casing diameter: 2.38"

Inside casing diameter: 2"

Casing joint type: threaded

Casing/screen joint type: threaded

Screen material: PVC

Screen opening size: 0.010"

Screen length: 5 ft

Depth of well: 28 ft

Filter Pack:

Material: Red Flint

Grain size: #40

Volume: 2 cubic ft.

Seal (minimum 3 ft length above filter pack):

Material: Hole Plug 3/8 inch

Placement method: Gravity

Volume: 6 cubic ft.

Backfill (if different from seal):

Material:

Placement method:

Volume:

Surface seal design:

Material of protective casing: Steel 6 inch

Material of grout between protective casing and well casing: sand

Protective cap:

Material: steel, vented

Vented: ☐ Yes ☒ No Locking: ☐ Yes ☐ No

Well Cap:

Material: PVC

Vented: ☐ Yes ☒ No

D. GROUNDWATER MEASURMENT (± 0.01 ft below top of inner well casing)

Water level: 13.95 Stabilization Time: <5 minutes

Well development method: Surged with block and pumped to reduce turbidity. 151 gallons pumped.

Average depth of frostline: 3.5'

Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½x11 inch map showing locations of all monitoring wells and piezometers.

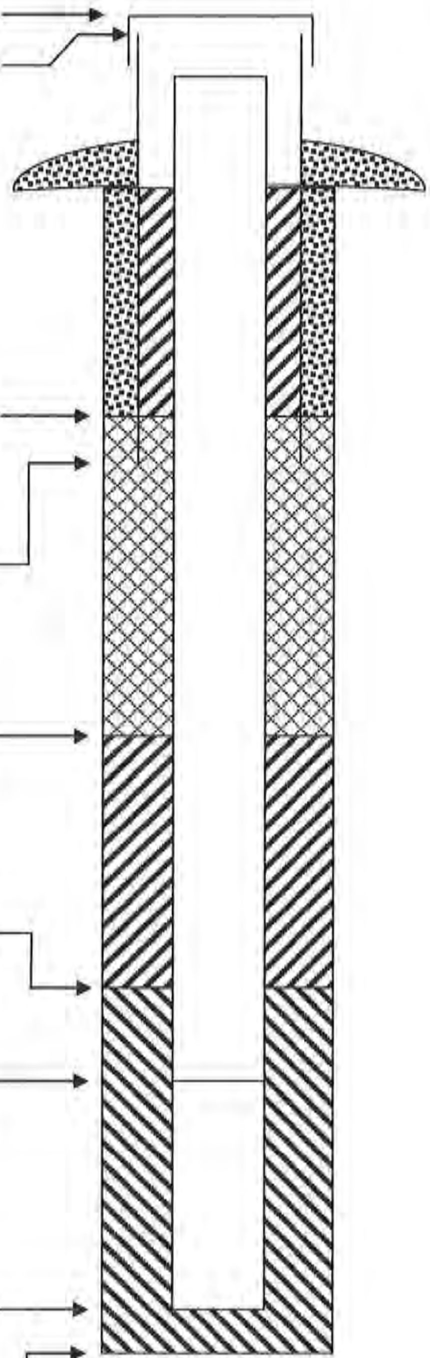
Please mail completed for to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E 9th St, Des Moines IA 50319-0034.

Questions? Call or Email: Nina Koger, Environmental Engineer Sr., 515-281-8986, Nina.Koger@dnr.iowa.gov

06/2011 cmz DNR Form 542-1277

ELEVATIONS: ± 0.01 ft MSL
DEPTHS: ± 0.1 ft FROM GROUND SURFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL.)



TOP OF PROTECTIVE CASING
ELEVATION 537.74

TOP OF WELL CASING
ELEVATION 537.2

GROUND SURFACE
ELEVATION 534.89

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 532.89
DEPTH 2.0

BASE OF PROTECTIVE CASING
ELEVATION 532.39
DEPTH 2.5

BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 513.89
DEPTH 21

TOP OF SCREEN
ELEVATION 511.89
DEPTH 23

BOTTOM OF SCREEN
ELEVATION 506.89
DEPTH 28

BASE OF FILTER PACK
ELEVATION 505.39
DEPTH 29.5

Print Form

IOWA DEPARTMENT OF NATURAL RESOURCES

MONITORING WELL/PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL - Burlington Generating Station   Permit No.:

Well or Piezometer No: MW-309

Dates Started: 3/1/16   Date Completed: 3/1/16

A. SURVEYED LOCATIONS AND ELEVATIONS

Locations (± 0.5 ft):

Specify corner of site: NE of Parcel 16-29-300-007

Distance & direction along boundary: 141' S

Distance & direction from boundary to wall: 123' W

Elevations (± 0.01 ft MSL):

Ground Surface: 534.11

Top of protective casing: 536.70

Top of well casing: 536.42

Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Name & Address of Construction Company:

Direct Push Analytical Corp

4N969 Old LaFox Road, Unit E

St. Charles, IL 60175

Name of Driller: Kevin Collins

Drilling Method: Direct Push/4.25" HSA

Drilling Fluid: NA

Bore Hole Diameter: 8.5 inch

Soil Sampling Method: Macro Core

Depth of Boring: 25 ft bgs

C. MONITORING WELL INSTALLATION

Casing material: PVC

Length of casing: 20

Outside casing diameter: 2.38"

Inside casing diameter: 2"

Casing joint type: threaded

Casing/screen joint type: threaded

Screen material: PVC with slip cap and 4 stainless screws

Screen opening size: 0.010"

Screen length: 5 ft

Depth of well: 25

Filter Pack:

Material: NSF R.W Sidley Inc.

Grain size: 10/20

Volume: 1.50 cubic ft.

Seal (minimum 3 ft length above filter pack):

Material: Black Hills Bentonite 3/8 inch

Placement method: Gravity

Volume: 2 cubic ft.

Backfill (if different from seal):

Material: 3/8 Hole Plug

Placement method: Gravity

Volume:

Surface seal design:

Material of protective casing: Steel 4 inch

Material of grout between protective casing and well casing: sand

Protective cap:

Material: steel, vented

Vented: ☐ Yes ☐ No   Locking: ☒ Yes ☐ No

Well Cap:

Material: PVC

Vented: ☐ Yes ☒ No

D. GROUNDWATER MEASURMENT (± 0.01 ft below top of inner well casing)

Water level: 13.18   Stabilization Time: <5 minutes

Well development method: Surged with block and pumped to reduce turbidity. 140 gallons pumped.

Average depth of frostline:

Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½x11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed for to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E 9th St, Des Moines IA 50319-0034.

Questions? Call or Email: Nina Koger, Environmental Engineer Sr., 515-281-8986, Nina.Koger@dnr.iowa.gov

ELEVATIONS: ± 0.01 ft MSL
DEPTHS: ± 0.1 ft FROM GROUND SURFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL.)

TOP OF PROTECTIVE CASING
ELEVATION 536.7

TOP OF WELL CASING
ELEVATION 536.42

GROUND SURFACE
ELEVATION 534.11

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 532.11
DEPTH 2

BASE OF PROTECTIVE CASING
ELEVATION 531.61
DEPTH 2.5

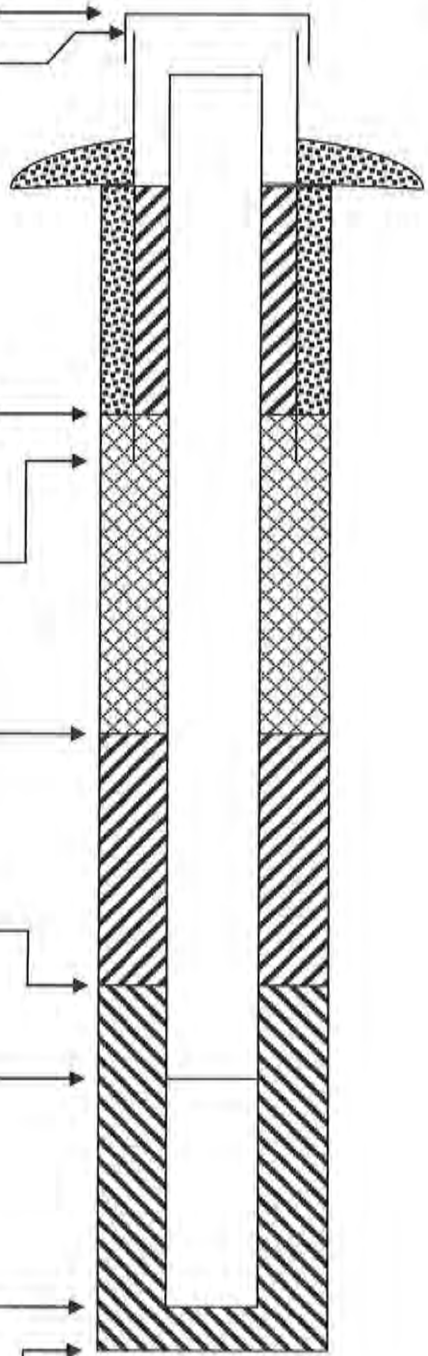
BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 516.11
DEPTH 18

TOP OF SCREEN
ELEVATION 514.11
DEPTH 20

BOTTOM OF SCREEN
ELEVATION 509.11
DEPTH 25

BASE OF FILTER PACK
ELEVATION 509.11
DEPTH 25



Print Form

IOWA DEPARTMENT OF NATURAL RESOURCES

MONITORING WELL/PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL - Burlington Generating Station Permit No.:

Well or Piezometer No: MW-310

Dates Started: 3/1/16 Date Completed: 3/1/16

A. SURVEYED LOCATIONS AND ELEVATIONS

Locations (± 0.5 ft):

Specify corner of site: Sullivan Slough RD West ROW

Distance & direction along boundary: 65' S from RR Tracks

Distance & direction from boundary to wall: 21' W

Elevations (± 0.01 ft MSL):

Ground Surface: 532.23

Top of protective casing: 532.23

Top of well casing: 531.99

Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Name & Address of Construction Company:
Direct Push Analytical Corp
4N969 Old LaFox Road, Unit E
St. Charles, IL 60175

Name of Driller: Kevin Collins

Drilling Method: Direct Push/4.25" HSA

Drilling Fluid: NA

Bore Hole Diameter: 8.5 inch

Soil Sampling Method: Macro Core

Depth of Boring: 24 ft bgs

C. MONITORING WELL INSTALLATION

Casing material: PVC

Length of casing: 14

Outside casing diameter: 2.38"

Inside casing diameter: 2"

Casing joint type: threaded

Casing/screen joint type: threaded

Screen material: PVC with slip cap and 4 stainless screws

Screen opening size: 0.010"

Screen length: 5 ft

Depth of well: 19 ft bgs

Filter Pack:

Material: NSF R.W Sidley Inc.

Grain size: 10/20

Volume: 1 cubic ft.

Seal (minimum 3 ft length above filter pack):

Material: Black Hills Bentonite 3/8 inch

Placement method: Gravity

Volume: 2.7 cubic ft.

Backfill (if different from seal):

Material:

Placement method:

Volume:

Surface seal design:

Material of protective casing: Steel 4 inch

Material of grout between protective casing and well casing: sand

Protective cap:

Material: Steel, not vented, flush-mount

Vented: ☐ Yes ☐ No Locking: ☒ Yes ☐ No

Well Cap:

Material: PVC

Vented: ☐ Yes ☒ No

D. GROUNDWATER MEASURMENT (± 0.01 ft below top of inner well casing)

Water level: 6.58 Stabilization Time: <5 minutes

Well development method: Surged with block and pumped to reduce turbidity. 112.5 gallons pumped.

Average depth of frostline: 3.5

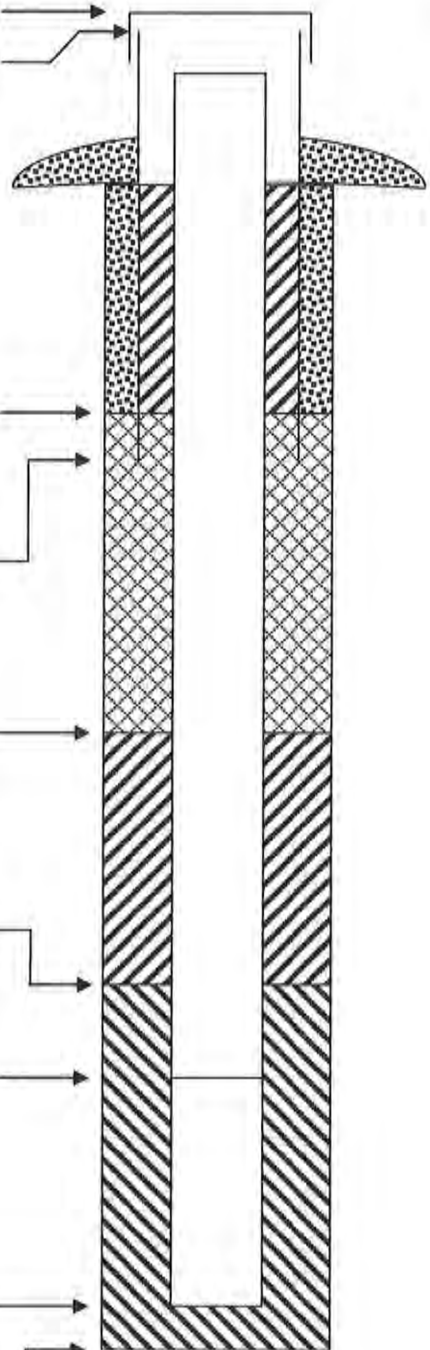
Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½x11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed for to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E 9th St, Des Moines IA 50319-0034.

Questions? Call or Email: Nina Koger, Environmental Engineer Sr., 515-281-8986, Nina.Koger@dnr.iowa.gov

ELEVATIONS: ± 0.01 ft MSL
DEPTHS: ± 0.1 ft FROM GROUND SURFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL.)



TOP OF PROTECTIVE CASING
ELEVATION 532.23

TOP OF WELL CASING
ELEVATION 531.99

GROUND SURFACE
ELEVATION 532.23

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 530.23
DEPTH 2

BASE OF PROTECTIVE CASING
ELEVATION 529.73
DEPTH 2.5

BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 520.23
DEPTH 12

TOP OF SCREEN
ELEVATION 518.23
DEPTH 14

BOTTOM OF SCREEN
ELEVATION 513.23
DEPTH 19

BASE OF FILTER PACK
ELEVATION 508.23
DEPTH 24

MONITORING WELL / PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: Burlington Generating Station Permit No.:

Well or Piezometer No.: MW-310A Dates Started: 6/25/2020 Date Completed: 6/26/2020

A. SURVEYED LOCATION AND ELEVATION OF POINT (+0.5 ft.)

Specify corner of site: Sullivan SloughRd WestROW Distance and direction along boundary: 75' S from RR Tracks

Distance and direction from boundary to surface monitoring well: 21' W

Elevation (+0.01 ft. MSL):

Ground Surface: 532.91' Top of protective casing: 532.91'

Top of well casing: 532.53' Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Construction Company Name: Roberts Environmental Drilling

Address: 1107 S Mulberry St City, State, Zip Code: Millstadt, IL 62260

Name of driller: Jeff Crank

Drilling method: Hollow Stem Auger Drilling fluid: Water Bore Hole diameter: 4.25"

Soil sampling method: Split spoon Depth of boring: 50'

C. MONITORING WELL INSTALLATION

Casing material: Sch. 40 PVC

Length of casing: 49.4'

Outside casing diameter: 2.4"

Inside casing diameter: 2"

Casing joint type: Threaded

Casing/screen joint type: Threaded

Screen material: Sch. 40 PVC

Screen opening size: 0.01

Screen length: 5'

Depth of Well: 49'

Filter Pack:
- Material: Sand (FilterSil)
- Grain Size: 18-23
- Volume: 3, 50lbs bags

Seal (minimum 3 ft. length above filter pack):
- Material: Bentonite grout

Placement method: Pumped

Volume: 8, 50lbs bags (~130 gallons of grout)

Backfill (if different from seal):
- Material: 3/8" Bentonite chips
- Placement method: Poured
- Volume: 23, 50lbs bags

Surface seal design: Flush mount
- Material of protective casing: steel
- Material of grout between protective casing and well casing: Bentonite chips

Protective cap:
- Material: Steel
- Vented?: ☐ Y ☒ N Locking?: ☐ Y ☒ N

Well cap: Lockable expanding well plug
- Material: Plastic
- Vented?: ☐ Y ☒ N

D. GROUNDWATER MEASUREMENT (+0.01 foot below top of inner well casing)

Water level 8.77' **Stabilization time** >48 hrs

Well development method Surged with bailer and pumped

Average depth of frost line 4'

DRILLER'S CERTIFICATION

I certify under penalty of law I believe the information reported above is true, accurate, and complete.

Signature: Jeff Crank **Certification #** 8515 **Date** 9-16-20

Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½ inch x 11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed form to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E. 9th St, Des Moines, IA 50319.
Questions? Call or Email: Nina Booker Environmental Engineer Sr., 515-725-8309, nina.booker@dnr.iowa.gov

ELEVATIONS: ± 0.01 FT. MSL

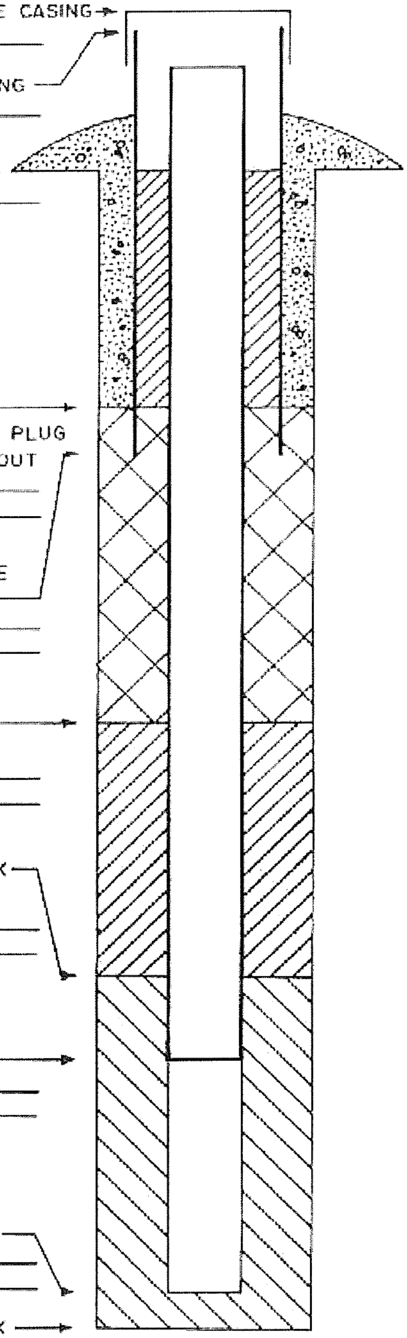
DEPTHS: ± 0.1 FT. FROM GROUND SERFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL).

TOP OF PROTECTIVE CASING
ELEVATION 532.91

TOP OF WELL CASING
ELEVATION 532.53

GROUND SURFACE
ELEVATION 532.91



TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION
DEPTH 1'

BASE OF PROTECTIVE
CASING
ELEVATION
DEPTH 1'

BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH 41'

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION
DEPTH 41'

TOP OF SCREEN
ELEVATION 44'
DEPTH 44'

BOTTOM OF SCREEN
ELEVATION
DEPTH 49'

BASE OF FILTER PACK
ELEVATION
DEPTH 50'

Print Form

IOWA DEPARTMENT OF NATURAL RESOURCES

MONITORING WELL/PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL - Burlington Generating Station   Permit No.:

Well or Piezometer No: MW-311

Dates Started: 3/1/16   Date Completed: 3/1/16

A. SURVEYED LOCATIONS AND ELEVATIONS

Locations (± 0.5 ft):

Specify corner of site: Sullivan Slough RD West ROW

Distance & direction along boundary: 207' S from RR Tracks

Distance & direction from boundary to wall: 18' W

Elevations (± 0.01 ft MSL):

Ground Surface: 532.69

Top of protective casing: 532.69

Top of well casing: 532.32

Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Name & Address of Construction Company:
Direct Push Analytical Corp
4N969 Old LaFox Road, Unit E
St. Charles, IL 60175

Name of Driller: Kevin Collins

Drilling Method: Direct Push/4.25" HSA

Drilling Fluid: NA

Bore Hole Diameter: 8.5 inch

Soil Sampling Method: Macro Core

Depth of Boring: 32 ft bgs

C. MONITORING WELL INSTALLATION

Casing material: PVC

Length of casing: 18

Outside casing diameter: 2.38"

Inside casing diameter: 2"

Casing joint type: threaded

Casing/screen joint type: threaded

Screen material: PVC with slip cap and 4 stainless screws

Screen opening size: 0.010"

Screen length: 5

Depth of well: 23

Filter Pack:

Material: NSF R.W Sidley Inc.

Grain size: 10/20

Volume: 1 cubic ft.

Seal (minimum 3 ft length above filter pack):

Material: Black Hills Bentonite 3/8 inch

Placement method: Gravity

Volume: 3.7 cubic ft.

Backfill (if different from seal):

Material:

Placement method:

Volume:

Surface seal design:

Material of protective casing: Steel 4 inch

Material of grout between protective casing and well casing: sand

Protective cap:

Material: steel, not vented, flush-mount

Vented: ☐ Yes ☐ No   Locking: ☒ Yes ☐ No

Well Cap:

Material: PVC

Vented: ☐ Yes ☒ No

D. GROUNDWATER MEASURMENT (± 0.01 ft below top of inner well casing)

Water level: 8.34 ft   Stabilization Time: <5 minutes

Well development method: Surged with block and pumped to reduce turbidity. 99 gallons pumped.

Average depth of frostline: 3.5'

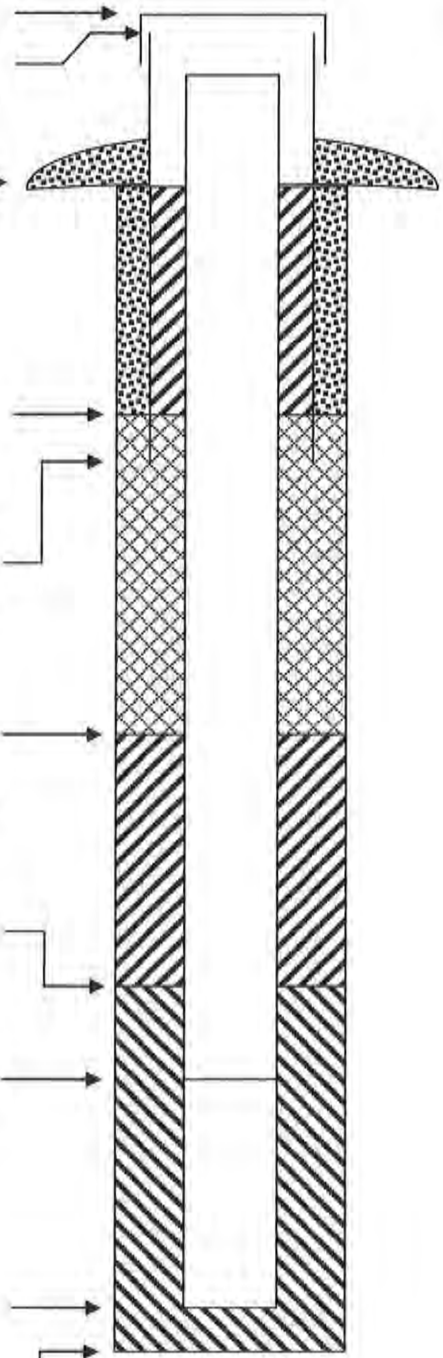
Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½x11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed for to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E 9th St, Des Moines IA 50319-0034.

Questions? Call or Email: Nina Koger, Environmental Engineer Sr., 515-281-8986, Nina.Koger@dnr.iowa.gov

ELEVATIONS: ± 0.01 ft MSL
DEPTHS: ± 0.1 ft FROM GROUND SURFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL.)



TOP OF PROTECTIVE CASING
ELEVATION 532.69
TOP OF WELL CASING
ELEVATION 532.32

GROUND SURFACE
ELEVATION 532.69

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 530.69
DEPTH 2

BASE OF PROTECTIVE CASING
ELEVATION 530.19
DEPTH 2.5

BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 516.69
DEPTH 16

TOP OF SCREEN
ELEVATION 514.69
DEPTH 18

BOTTOM OF SCREEN
ELEVATION 509.69
DEPTH 23

BASE OF FILTER PACK
ELEVATION 500.69
DEPTH 32

MONITORING WELL / PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL Burlington Generating Station Permit No.:

Well or Piezometer No.: MW312 Dates Started: 5/20/2019 Date Completed: 5/21/2019

A. SURVEYED LOCATION AND ELEVATION OF POINT (+0.5 ft.)

Specify corner of site: SE Distance and direction along boundary: 1,400 N

Distance and direction from boundary to surface monitoring well: 200 W

Elevation (+0.01 ft. MSL):

Ground Surface: 533.80 Top of protective casing: 536.83

Top of well casing: 536.43 Benchmark elevation:

Benchmark description:

B. SOIL BORING INFORMATION

Construction Company Name: Roberts Environmental Drilling, Inc.

Address: 1107 S Mullberry St. City, State, Zip Code: Millstadt, IL 62260

Name of driller: Jeff Crank

Drilling method: 4.25" HSA Drilling fluid: Bore Hole diameter: 8.5"

Soil sampling method: split spoon Depth of boring: 26'

C. MONITORING WELL INSTALLATION

Casing material: PVC
Length of casing: 27.65
Outside casing diameter: 2.4"
Inside casing diameter: 2.0"
Casing joint type: threaded
Casing/screen joint type: threaded
Screen material: PVC
Screen opening size: 0.01"
Screen length: 5'
Depth of Well: 25'
Filter Pack:
  Material: filter sand
  Grain Size: #5
  Volume: 3 cu. ft.
Seal (minimum 3 ft. length above filter pack):
  Material: Bentonite chips

Placement method: gravity
Volume: 5 cu. ft.
Backfill (if different from seal):
  Material:
  Placement method:
  Volume:
Surface seal design: Concrete
  Material of protective casing: Steel
  Material of grout between protective casing and well casing: Bentonite
Protective cap:
  Material: Steel
  Vented?: [X] Y [ ] N Locking?: [X] Y [ ] N
Well cap: Low-flow purge cap
  Material: Plastic
  Vented?: [ ] Y [X] N

D. GROUNDWATER MEASUREMENT (+0.01 foot below top of inner well casing)

Water level 4.85 **Stabilization time** < 1 hr

Well development method Surged and pumped to remove turbidity

Average depth of frost line 4 ft

DRILLER'S CERTIFICATION

I certify under penalty of law I believe the information reported above is true, accurate, and complete.

Signature [signature] **Certification #** 8515 **Date** 8/8/2019

Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½ inch x 11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed form to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E. 9th St, Des Moines, IA 50319.
Questions? Call or Email: Nina Booker Environmental Engineer Sr., 515-725-8309, nina.booker@dnr.iowa.gov

09/2017 cmc DNR Form 542-1277

ELEVATIONS: ± 0.01 FT. MSL

DEPTHS: ± 0.1 FT. FROM
GROUND SERFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL)

TOP OF PROTECTIVE CASING
ELEVATION 536.83

TOP OF WELL CASING
ELEVATION 536.43

GROUND SURFACE
ELEVATION 533.80

TOP OF BACKFILL
BASE OF CONCRETE PLUG
AND BENTONITE GROUT
ELEVATION 529.8
DEPTH 4

BASE OF PROTECTIVE
CASING
ELEVATION 529.8
DEPTH 4

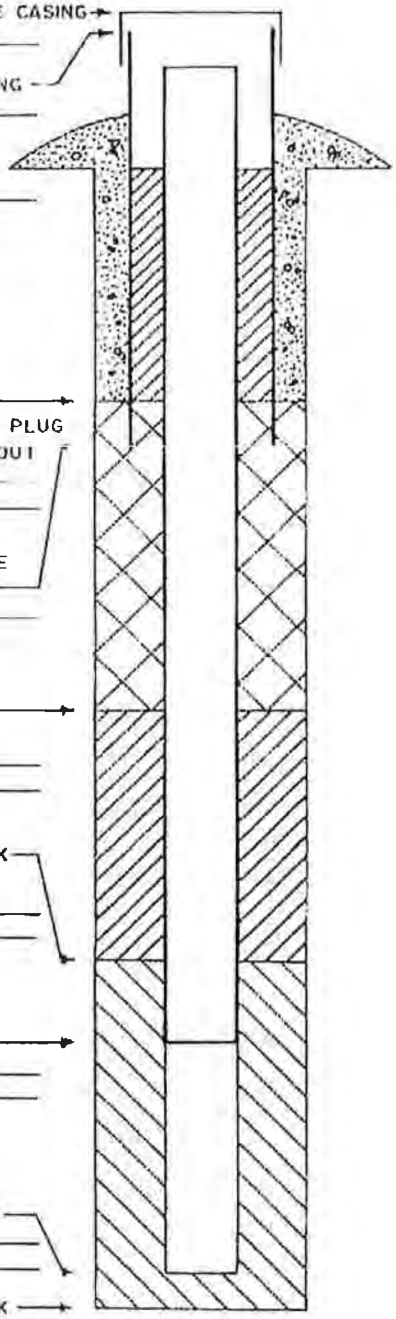
BASE OF BACKFILL
TOP OF SEAL
ELEVATION
DEPTH

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 515.8
DEPTH 18

TOP OF SCREEN
ELEVATION 513.8
DEPTH 20

BOTTOM OF SCREEN
ELEVATION 508.8
DEPTH 25

BASE OF FILTER PACK
ELEVATION 507.8
DEPTH 26



MONITORING WELL / PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: IPL Burlington Generating Station Permit No. ____

Well or Piezometer No.: MW313 Dates Started: 5/21/2019 Date Completed: 5/22/2019

A. SURVEYED LOCATION AND ELEVATION OF POINT (+0.5 ft.)

Specify corner of site: SE Distance and direction along boundary: 890 N

Distance and direction from boundary to surface monitoring well: 130 E

Elevation (+0.01 ft. MSL): ____

Ground Surface: 533.97 Top of protective casing: 536.18

Top of well casing: 535.82 Benchmark elevation: ____

Benchmark description: ____

B. SOIL BORING INFORMATION

Construction Company Name: Roberts Environmental Drilling, Inc.

Address: 1107 S Mullberry St. City, State, Zip Code: Millstadt, IL 62260

Name of driller: Jeff Crank

Drilling method: 4.25" HSA Drilling fluid: water Bore Hole diameter: 8.5"

Soil sampling method: split spoon Depth of boring: 32'

C. MONITORING WELL INSTALLATION

Casing material: PVC
Length of casing: 32.99'
Outside casing diameter: 2.4"
Inside casing diameter: 2.0"
Casing joint type: threaded
Casing/screen joint type: threaded
Screen material: PVC
Screen opening size: 0.01"
Screen length: 5'
Depth of Well: 31'
Filter Pack: ____
- Material: filter sand
- Grain Size: #5
- Volume: 3 cu. ft.

Seal (minimum 3 ft. length above filter pack): ____
- Material: Bentonite chips

Placement method: gravity
Volume: 7 cu. ft.
Backfill (if different from seal): ____
- Material: ____
- Placement method: ____
- Volume: ____

Surface seal design: Concrete
- Material of protective casing: Steel
- Material of grout between protective casing and well casing: Bentonite

Protective cap: ____
- Material: steel
- Vented?: ☒ Y ☐ N Locking?: ☒ Y ☐ N

Well cap: Low-flow purge cap
- Material: Plastic
- Vented?: ☐ Y ☒ N

D. GROUNDWATER MEASUREMENT (+0.01 foot below top of inner well casing)

Water level 4.25 **Stabilization time** < 1 hr

Well development method Surged and pumped to remove turbidity

Average depth of frost line 4 ft

DRILLER'S CERTIFICATION

I certify under penalty of law I believe the information reported above is true, accurate, and complete.

Signature [signature] **Certification #** 8515 **Date** 8/8/2019

Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½ inch x 11 inch map showing locations of all monitoring wells and piezometers.

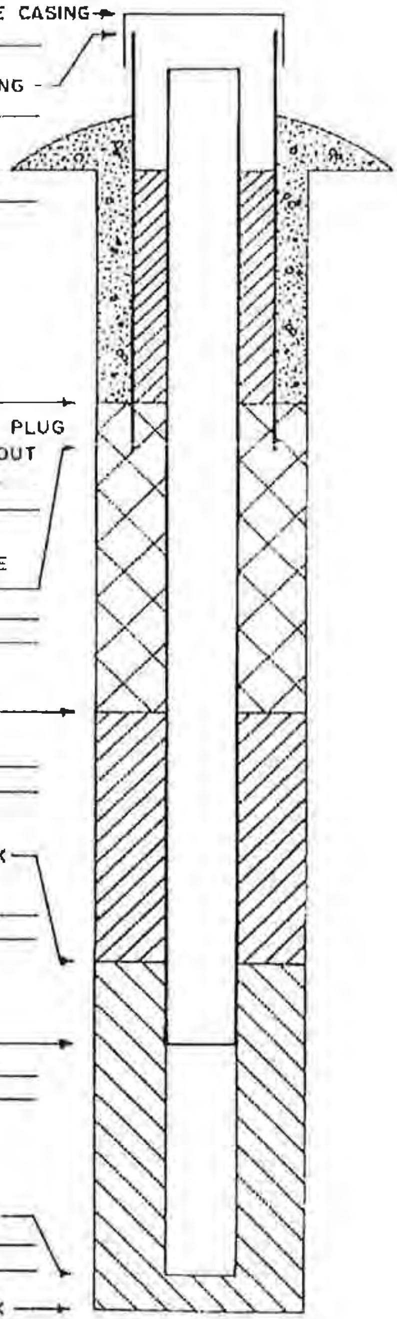
Please mail completed form to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E. 9th St, Des Moines, IA 50319.
Questions? Call or Email: Nina Booker Environmental Engineer Sr., 515-725-8309, nina.booker@dnr.iowa.gov

09/2017 cmc DNR Form 542-1277

ELEVATIONS: ± 0.01 FT. MSL

DEPTHS: ± 0.1 FT. FROM GROUND SERFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL)



TOP OF PROTECTIVE CASING
ELEVATION 536.18

TOP OF WELL CASING
ELEVATION 535.82

GROUND SURFACE
ELEVATION 533.97

TOP OF BACKFILL
BASE OF CONCRETE PLUG AND BENTONITE GROUT
ELEVATION 529.5
DEPTH 4.5

BASE OF PROTECTIVE CASING
ELEVATION 529.2
DEPTH 4.8

BASE OF BACKFILL
TOP OF SEAL
ELEVATION N/A
DEPTH

TOP OF FILTER PACK
BASE OF SEAL
ELEVATION 510.0
DEPTH 24

TOP OF SCREEN
ELEVATION 508.0
DEPTH 26

BOTTOM OF SCREEN
ELEVATION 503.0
DEPTH 31

BASE OF FILTER PACK
ELEVATION 502.0
DEPTH 32

MONITORING WELL / PIEZOMETER CONSTRUCTION DOCUMENTATION FORM

Disposal Site Name: Burlington Generating Station Permit No.:
Well or Piezometer No.: MW-313A Dates Started: 6/23/2020 Date Completed: 6/30/2020

A. SURVEYED LOCATION AND ELEVATION OF POINT (+0.5 ft.)

Specify corner of site: SE Distance and direction along boundary: 890 N
Distance and direction from boundary to surface monitoring well: 130 E
Elevation (+0.01 ft. MSL):
Ground Surface: 529.35' Top of protective casing: 532.03'
Top of well casing: 531.63' Benchmark elevation:
Benchmark description:

B. SOIL BORING INFORMATION

Construction Company Name: Roberts Environmental Drilling
Address: 1107 S Mulberry St City, State, Zip Code: Millstadt, IL 62260
Name of driller: Jeff Crank
Drilling method: Hollow Stem Auger Drilling fluid: Water Bore Hole diameter: 4.25"
Soil sampling method: Split spoon Depth of boring: 62'

C. MONITORING WELL INSTALLATION

Casing material: Sch. 40 PVC
Length of casing: 63.38'
Outside casing diameter: 2.4"
Inside casing diameter: 2"
Casing joint type: Threaded
Casing/screen joint type: Threaded
Screen material: Sch. 40 PVC
Screen opening size: 0.01
Screen length: 5'
Depth of Well: 61'
Filter Pack:
Material: Sand (FilterSil)
Grain Size: 18-23
Volume: 2, 50lbs bags
Seal (minimum 3 ft. length above filter pack):
Material: Bentonite grout

Placement method: Pumped
Volume: 9, 50lbs bags (~150 gallons of grout)
Backfill (if different from seal):
Material: 3/8" Bentonite chips
Placement method: Poured
Volume: 3, 50lbs bags
Surface seal design: Concrete
Material of protective casing: steel
Material of grout between protective casing and well casing: Bentonite chips
Protective cap:
Material: Steel
Vented?: ☐ Y ☒ N Locking?: ☐ Y ☒ N
Well cap: Lockable expanding well plug
Material: Plastic
Vented?: ☐ Y ☒ N

D. GROUNDWATER MEASUREMENT (+0.01 foot below top of inner well casing)

Water level 14.41' **Stabilization time** < 5 min
Well development method Surged with bailer and pumped
Average depth of frost line 4'

DRILLER'S CERTIFICATION

I certify under penalty of law I believe the information reported above is true, accurate, and complete.

Signature Jeff Crank **Certification #** 8515 **Date** 9-16-20

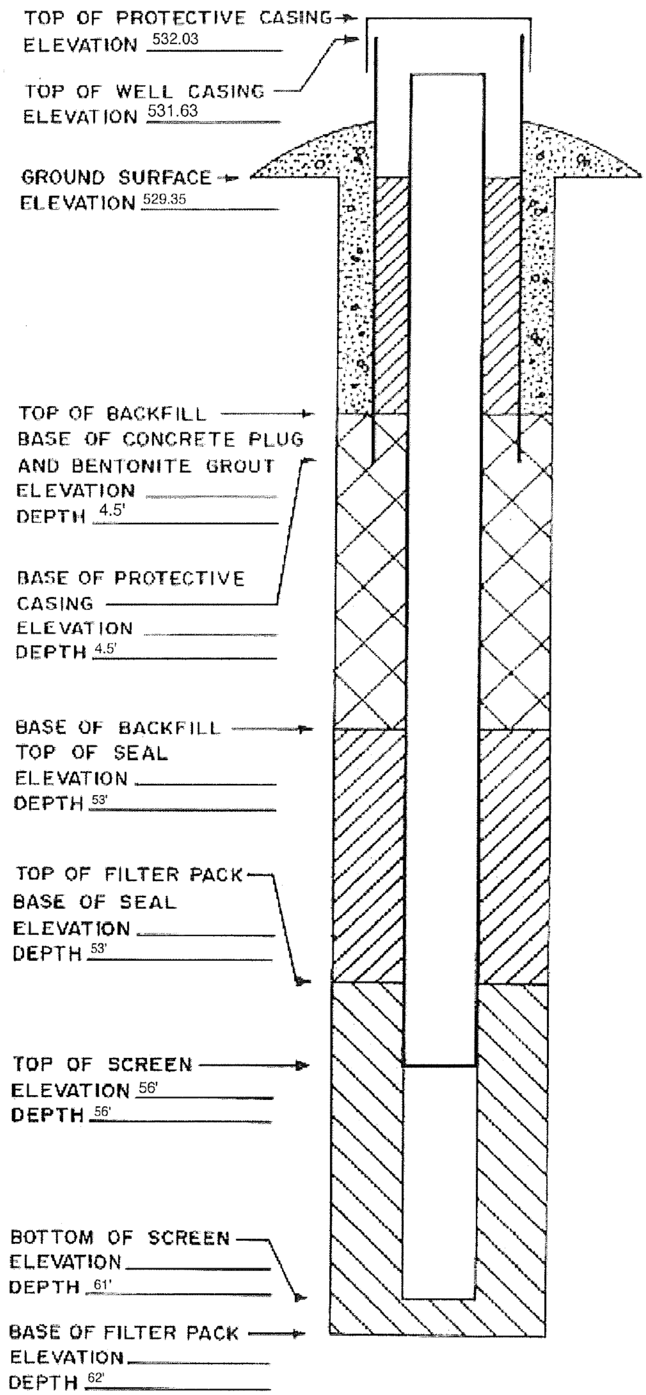
Attachments: Driller's log. Pipe schedules and grouting schedules. 8 ½ inch x 11 inch map showing locations of all monitoring wells and piezometers.

Please mail completed form to: Iowa Department of Natural Resources, Land Quality Bureau, 502 E. 9th St, Des Moines, IA 50319.
Questions? Call or Email: Nina Booker Environmental Engineer Sr., 515-725-8309, nina.booker@dnr.iowa.gov

ELEVATIONS: ± 0.01 FT. MSL

DEPTHS: ± 0.1 FT. FROM
GROUND SERFACE

SPACE TO ATTACH ENTIRE SOIL BORING LOG
(SHOW SCREENED INTERVAL AND FILTER PACK INTERVAL).



B2 Groundwater Monitoring Results

Single Location

Name: IPL - Burlington

Location ID: MW-301
Number of Sampling Dates: 16

Parameter Name	Units	4/20/2016	6/6/2016	8/16/2016	10/3/2016	1/10/2017	4/3/2017	6/12/2017	8/16/2017	10/16/2017	5/9/2018	8/13/2018	10/9/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020
Boron	ug/L	12400	10600	13100	10500	12000	14500	10500	14000	9900	9140	12800	8040	--	12000	8100	10000
Calcium	mg/L	156	100	178	131	140	220	156	211	140	85.3	174	103	--	150	130	140
Chloride	mg/L	23.3	22.4	22.3	21.6	21.3	20.7	21.5	20.8	22	22.7	21.7	21.5	--	21	20	22
Fluoride	mg/L	0.55	0.29	0.43	0.3	0.37	0.36	0.23	0.45	0.27	0.36	0.52	0.26	--	0.77	<0.23	0.26
pH at 25 Degrees C	Std. Units	7	7.1	7	7.2	7.2	7.4	6.9	7.1	7.2	7.2	7.2	7	--	7	7.1	7
Field pH	Std. Units	7.27	7.65	7.53	7.61	7.41	7.37	7.36	6.89	7.58	7.4	7.91	7.34	6.38	7.53	6.85	6.99
Sulfate	mg/L	193	170	206	378	385	215	511	327	454	188	187	358	--	190	390	250
Total Dissolved Solids	mg/L	782	630	857	729	816	1020	960	1190	780	568	960	656	--	890	690	910
Antimony	ug/L	0.062	0.12	0.13	0.073	<0.058	0.049	<0.026	0.2	--	<0.026	<0.15	0.08	--	<0.53	<0.53	<0.58
Arsenic	ug/L	39.4	35	44.1	36.9	39.7	46.1	33.4	42.7	--	34.9	40.1	37.7	--	42	40	46
Barium	ug/L	381	239	406	294	343	464	380	479	--	198	420	276	--	380	320	330
Beryllium	ug/L	<0.08	<0.08	<0.08	<0.08	<0.08	0.046	<0.012	0.014	--	<0.012	<0.12	<0.089	--	<0.27	<0.27	<0.27
Cadmium	ug/L	<0.029	<0.029	<0.029	<0.029	0.032	<0.018	<0.018	<0.018	--	0.04	<0.07	<0.033	--	<0.077	<0.039	<0.039
Chromium	ug/L	0.67	0.38	0.56	<0.34	0.44	0.34	0.17	0.49	--	0.25	0.36	0.12	--	<0.98	<0.98	<1.1
Cobalt	ug/L	0.64	<0.5	0.52	<0.5	<0.5	0.57	0.16	0.46	--	0.15	0.45	0.1	--	0.44	0.18	0.31
Lead	ug/L	0.31	<0.19	<0.19	<0.19	<0.19	0.091	0.12	0.23	--	0.17	0.13	<0.13	--	<0.27	<0.27	<0.27
Lithium	ug/L	10.3	11.7	<4.9	22.8	20.1	13.2	29.4	18.2	--	17.8	18.9	24.5	--	13	26	16
Mercury	ug/L	<0.046	<0.039	<0.039	<0.039	<0.055	<0.046	<0.046	<0.046	--	<0.09	--	<0.09	--	<0.1	--	<0.1
Molybdenum	ug/L	108	116	94.5	114	113	82.8	116	98.5	--	113	81.7	120	62.7	77	130	110
Selenium	ug/L	0.34	<0.18	0.29	<0.18	<0.18	0.4	0.1	0.35	--	0.25	0.28	0.13	--	<1	<1	<1
Thallium	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	0.08	0.08	0.059	--	<0.036	--	<0.099	--	<0.27	--	<0.26
Total Radium	pCi/L	1.33	0.933	2.03	0.643	0.512	1.16	1.86	1.81	--	0.712	1.15	1.5	--	1.15	1.03	0.928
Radium-226	pCi/L	0.6	0.144	0.367	0	0.0709	0.347	0.901	1.14	--	0.712	0.693	0.534	--	0.411	0.498	0.553
Radium-228	pCi/L	0.729	0.789	1.66	0.643	0.441	0.817	0.954	0.671	--	-0.016	0.459	0.966	--	0.736	0.527	0.376
Field Oxidation Potential	mV	-135.3	-110.7	-162.3	-156.4	-146.1	-164.7	-89.6	-90.4	38	-167.1	-145	-63.5	-73.1	-144.7	-162.9	37.1
Field Specific Conductance	umhos/cm	898	1702	2499	1776	1985	2507	859	1925	1065	600.8	1400	892	1055	1213	1063	1167
Field Temperature	deg C	12.6	13.2	13.5	14.1	13.6	12.9	13	13.8	13.8	12.9	16.8	17.2	12.56	12.35	13.9	13.4
Groundwater Elevation	feet	522.63	521.07	521.81	527.48	525.38	523.08	523.21	519.96	522.13	525.51	520.19	528.01	523.38	528.15	--	523.94
Oxygen, Dissolved	mg/L	0.09	1.12	0.11	0.5	0.1	0.12	0.17	0.05	0.12	0.08	0.35	0.24	2.61	0.59	0.23	0.25
Turbidity	NTU	10.49	1	0.51	0.54	0.9	1.12	2.02	0.4	1.26	4.23	5.78	8.43	17.1	21.1	12.55	20.15

Single Location

Name: IPL - Burlington

Location ID: MW-302
Number of Sampling Dates: 16

Parameter Name	Units	4/20/2016	6/6/2016	8/16/2016	10/3/2016	1/10/2017	4/3/2017	6/12/2017	8/15/2017	10/17/2017	5/9/2018	8/13/2018	10/9/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020
Boron	ug/L	8570	8400	9050	9500	9590	10100	10700	9450	10000	10200	10000	10400	--	12000	11000	13000
Calcium	mg/L	242	243	231	251	225	232	216	225	231	231	210	219	--	220	220	210
Chloride	mg/L	18.3	15.2	16.1	15.4	15.2	16.6	15	15.7	16.4	14.1	14.7	13.5	--	13	11	12
Fluoride	mg/L	0.11	<0.073	0.08	0.086	<0.027	<0.1	<0.1	<0.1	0.11	0.11	<0.063	<0.19	--	0.37	<0.23	<0.23
pH at 25 Degrees C	Std. Units	7.8	7.8	7.6	7.8	7.9	8	7.6	7.8	8	7.9	8	7.7	--	8.1	7.7	7.6
Field pH	Std. Units	8.17	8.06	8.3	8.24	8.22	8.71	8.06	8.38	8.72	8.19	9.32	7.89	6.94	8.7	7.49	7.88
Sulfate	mg/L	666	525	669	579	536	540	552	512	541	553	542	658	--	510	510	490
Total Dissolved Solids	mg/L	1040	1140	988	977	969	945	937	989	951	1080	1000	1030	--	1000	960	1000
Antimony	ug/L	0.14	0.15	<0.058	0.096	<0.058	0.043	0.04	0.16	--	<0.026	<0.15	0.082	--	<0.53	<0.53	<0.58
Arsenic	ug/L	71.3	68.4	64.1	73.5	64.9	49.1	72	58.5	--	56.2	49.6	76.4	--	53	73	110
Barium	ug/L	430	476	361	446	355	356	370	348	--	363	340	180	--	320	260	340
Beryllium	ug/L	<0.08	<0.08	<0.08	<0.08	<0.08	0.023	<0.012	0.012	--	<0.012	<0.12	<0.089	--	<0.27	<0.27	<0.27
Cadmium	ug/L	0.043	<0.029	<0.029	<0.029	<0.029	<0.018	0.021	<0.018	--	0.037	<0.07	0.04	--	<0.077	<0.039	0.045
Chromium	ug/L	<0.34	<0.34	0.45	<0.34	0.46	0.15	0.11	0.31	--	0.22	0.33	0.097	--	<0.98	<0.98	<1.1
Cobalt	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	0.19	0.24	0.24	--	0.19	0.15	0.18	--	0.19	0.23	0.21
Lead	ug/L	0.21	<0.19	<0.19	<0.19	<0.19	0.058	0.064	0.22	--	0.17	<0.12	<0.13	--	0.58	<0.27	<0.27
Lithium	ug/L	60.5	69.6	37.6	64.2	62.6	57.3	60.7	56.9	--	65.4	61.4	57.8	59.9	56	57	55
Mercury	ug/L	<0.046	<0.039	<0.039	<0.039	<0.055	<0.046	<0.046	<0.046	--	<0.09	--	<0.09	--	<0.1	--	<0.1
Molybdenum	ug/L	85.8	84.4	92.5	105	104	105	131	113	--	118	121	122	123	100	100	140
Selenium	ug/L	0.3	0.22	0.27	0.2	<0.18	0.24	0.23	0.24	--	0.25	0.22	0.23	--	<1	<1	<1
Thallium	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	0.04	0.078	0.41	--	<0.036	--	<0.099	--	<0.27	--	<0.26
Total Radium	pCi/L	1.82	1.11	0.202	1.24	1.59	1.13	1.84	1.2	--	1.51	1.53	2.15	--	0.872	0.644	0.626
Radium-226	pCi/L	0	0.392	0	0.803	0.604	0.639	0.713	0.238	--	0.621	0.443	1.1	--	0.362	0.374	0.263
Radium-228	pCi/L	1.82	0.715	0.202	0.439	0.987	0.494	1.13	0.962	--	0.886	1.09	1.05	--	0.51	0.27	0.363
Field Oxidation Potential	mV	-181.1	-147	-167.1	-194.3	-182.6	-227.8	-154.4	-179.2	-49.7	-217.2	-237	-198	-70.3	-215.8	-186.8	36.7
Field Specific Conductance	umhos/cm	1032	2053	34.4	2202	2167	2037	833	1752	1165	1268	1226	1334	792	1164	1249	1245
Field Temperature	deg C	12.7	12.7	13.6	13.8	13.7	13.2	12.94	13.7	13.9	13	14.9	15.2	12.16	11.41	14.46	12.9
Groundwater Elevation	feet	521.91	521.21	521.35	527.54	525.5	522.84	522.84	519.39	522.2	525.81	519.87	528.08	522.83	528.21	--	523.98
Oxygen, Dissolved	mg/L	0.1	0.8	9.35	0.39	0.21	0.12	0.13	0.18	0.09	1	0.15	0.3	2.68	0.58	0.28	0.18
Turbidity	NTU	10.65	2.56	0.19	1.36	0.47	1.99	0.59	0.25	2.04	2.25	3.75	6.48	22.1	18.8	1.16	25.27

Single Location

Name: IPL - Burlington

Location ID: MW-302A

Number of Sampling Dates: 1

Parameter Name	Units	9/9/2020
Boron	ug/L	11000
Calcium	mg/L	120
Chloride	mg/L	27
Fluoride	mg/L	<0.23
Field pH	Std. Units	7.31
Sulfate	mg/L	340
Total Dissolved Solids	mg/L	730
Antimony	ug/L	<0.51
Arsenic	ug/L	2.9
Barium	ug/L	270

Location ID: MW-302A		
Number of Sampling Dates: 1		
Parameter Name	**Units**	**9/9/2020**
Beryllium	ug/L	<0.27
Cadmium	ug/L	<0.049
Chromium	ug/L	<1.1
Cobalt	ug/L	0.12
Lead	ug/L	0.11
Lithium	ug/L	11
Mercury	ug/L	<0.1
Molybdenum	ug/L	120
Selenium	ug/L	<1
Thallium	ug/L	<0.26
Field Oxidation Potential	mV	-142
Field Specific Conductance	umhos/cm	1013
Field Temperature	deg C	13.3

Location ID: MW-302A		
Number of Sampling Dates: 1		
Parameter Name	**Units**	**9/9/2020**
Groundwater Elevation	feet	519.71
Turbidity	NTU	0.01
pH	Std. Units	7.4

Single Location

Name: IPL - Burlington

Location ID: MW-303
Number of Sampling Dates: 16

Parameter Name	Units	4/20/2016	6/6/2016	8/16/2016	10/3/2016	1/10/2017	4/3/2017	6/12/2017	8/15/2017	10/17/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020
Boron	ug/L	25800	27500	26700	26100	25400	28800	26600	24100	25400	22900	24500	24500	--	22000	21000	23000
Calcium	mg/L	86.3	79.9	81.3	87.8	71.2	88.6	105	79.4	84.5	87	85.9	87.8	--	86	91	120
Chloride	mg/L	17	16	16.3	16.1	14.4	15.2	17.3	15.3	15.3	15.1	15.7	16.3	--	15	16	18
Fluoride	mg/L	0.43	0.16	0.28	0.28	0.18	0.2	0.22	0.24	0.25	0.22	0.44	0.27	--	0.43	<0.23	0.27
pH at 25 Degrees C	Std. Units	7.2	7.4	7.2	7.3	7.6	7.6	6.9	7.2	7.3	7.4	7.3	7.1	--	7.4	7.4	7.2
Field pH	Std. Units	7.39	7.48	7.57	7.56	7.64	7.57	7.24	6.97	8.59	7.51	8.03	7.1	6.46	7.79	7.13	7.12
Sulfate	mg/L	34.6	23.3	14.8	6.6	34.1	24.1	3.9	46	42.1	128	78.7	31.8	--	120	84	100
Total Dissolved Solids	mg/L	450	441	440	447	404	454	557	434	436	502	520	462	--	540	420	640
Antimony	ug/L	0.55	0.12	<0.058	0.09	<0.058	0.029	<0.026	0.13	--	<0.026	<0.15	<0.078	--	<0.53	<0.53	<0.58
Arsenic	ug/L	38.6	26.5	44.5	33	12.8	21.7	48.1	30.9	--	7.9	52	29.8	--	6.4	17	18
Barium	ug/L	361	250	230	237	267	334	386	281	--	412	354	415	--	440	440	610
Beryllium	ug/L	0.9	<0.08	<0.08	<0.08	<0.08	0.019	0.018	0.02	--	<0.012	<0.12	<0.089	--	<0.27	<0.27	<0.27
Cadmium	ug/L	0.58	<0.029	<0.029	<0.029	<0.029	<0.018	<0.018	0.018	--	0.028	<0.07	<0.033	--	<0.077	<0.039	<0.039
Chromium	ug/L	23.4	0.48	0.4	<0.34	0.78	0.2	0.43	0.38	--	0.27	0.29	0.69	--	<0.98	<0.98	<1.1
Cobalt	ug/L	7.8	0.56	0.55	0.64	<0.5	0.38	0.68	0.42	--	0.31	0.46	0.62	--	0.36	0.45	0.56
Lead	ug/L	21	<0.19	<0.19	<0.19	0.21	0.047	<0.033	0.14	--	0.21	0.22	0.54	--	0.49	<0.27	0.29
Lithium	ug/L	35.8	34.6	24	30.3	48.8	46.6	26.2	45.1	--	50.7	42.1	35.8	51.6	52	46	48
Mercury	ug/L	<0.046	<0.039	<0.039	<0.039	<0.055	<0.046	<0.046	<0.046	--	<0.09	--	<0.09	--	<0.1	--	<0.1
Molybdenum	ug/L	67.4	55.4	39.4	34.2	52.8	51.7	33.8	73.1	--	75.4	77.9	56.5	--	110	76	66
Selenium	ug/L	2.2	<0.18	0.3	0.22	0.26	0.28	0.3	0.23	--	0.19	0.24	0.33	--	<1	<1	<1
Thallium	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	0.063	<0.036	0.13	--	<0.036	--	<0.099	--	<0.27	--	<0.26
Total Radium	pCi/L	2.18	0.522	1.59	0.464	1.98	1.53	1.86	2.19	--	1.64	1.79	1.91	--	1.26	1.04	0.892
Radium-226	pCi/L	0.866	0	0.269	0.393	0.677	0.542	0.734	1.37	--	0.677	0.462	0.997	--	0.552	0.728	0.804
Radium-228	pCi/L	1.31	0.522	1.32	0.0706	1.3	0.99	1.13	0.821	--	0.965	1.33	0.913	--	0.703	0.316	0.0877
Field Oxidation Potential	mV	-101.6	-113	-184.4	-164.5	-150.6	-163.9	-102.9	-132	21.3	-165.5	-153	-132	-68.1	-122.8	-161	58.1
Field Specific Conductance	umhos/cm	513	1009	1271	1175	1024	1100	599.8	887	612.6	535.7	748	774	549	711	767	934
Field Temperature	deg C	13.8	13.9	14.2	14.8	14.3	14.1	14.2	14.4	14.5	13.8	16.8	15.6	13.62	12.63	14.91	14.8
Groundwater Elevation	feet	521.76	521.26	521.31	527.57	525.56	522.81	522.8	519.3	522.23	525.8	519.78	528.78	522.74	528.22	--	523.97
Oxygen, Dissolved	mg/L	0.08	1.02	1.31	0.48	0.1	0.1	0.2	0.07	0.13	0.11	0.24	1	2.38	0.67	0.26	0.18
Turbidity	NTU	487.4	2.45	0.24	3.76	3.85	4.42	2.57	0.46	2.79	0.97	14.26	17.3	19.4	18.2	5.36	16.03

Single Location

Name: IPL - Burlington

Location ID: MW-304
Number of Sampling Dates: 16

Parameter Name	Units	4/20/2016	6/6/2016	8/16/2016	10/3/2016	1/9/2017	4/3/2017	6/12/2017	8/15/2017	10/17/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020
Boron	ug/L	5020	5050	5050	4910	5350	5340	5160	5370	5580	5140	5440	6180	--	6300	5100	6400
Calcium	mg/L	142	137	144	155	136	118	90.1	97.2	103	107	102	88.5	--	72	140	150
Chloride	mg/L	34.7	30	28.2	30.7	47.7	39.2	35.2	30.2	46.5	58.1	25.9	50.3	--	39	25	21
Fluoride	mg/L	0.092	<0.073	<0.027	0.072	<0.027	<0.1	<0.1	<0.1	0.12	0.11	0.13	<0.19	--	0.35	<0.23	<0.23
pH at 25 Degrees C	Std. Units	8.8	8.9	8.8	8.8	8.2	7.9	7.9	8.8	8.9	8.3	7.5	8.6	--	8	7.5	7.4
Field pH	Std. Units	9.2	8.65	9.42	9.25	9.44	8.58	7.93	8.71	9.52	8.51	7.6	9.01	6.94	8.56	7.17	7.23
Sulfate	mg/L	397	324	383	431	330	263	211	216	248	273	188	271	--	140	220	250
Total Dissolved Solids	mg/L	706	678	718	721	651	593	519	501	540	657	551	537	--	460	710	750
Antimony	ug/L	0.77	0.77	0.76	0.51	0.8	0.63	0.51	0.88	--	0.75	0.3	0.77	--	0.66	<0.53	<0.58
Arsenic	ug/L	60	59.4	64.3	58.9	68.7	60	58.4	65.6	--	57.2	45.4	58.3	--	59	36	35
Barium	ug/L	112	127	115	130	117	131	126	84.7	--	115	140	92	--	90	210	220
Beryllium	ug/L	<0.08	<0.08	<0.08	<0.08	<0.08	0.036	<0.012	<0.012	--	<0.012	<0.12	<0.089	--	<0.27	<0.27	<0.27
Cadmium	ug/L	<0.029	<0.029	<0.029	<0.029	<0.029	<0.018	<0.018	<0.018	--	<0.018	<0.07	0.054	--	<0.077	<0.039	<0.039
Chromium	ug/L	<0.34	<0.34	0.58	0.42	<0.34	0.16	0.087	0.3	--	0.22	0.34	0.091	--	<0.98	<0.98	<1.1
Cobalt	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	0.13	0.11	0.1	--	0.098	<0.15	0.19	--	0.11	0.13	0.15
Lead	ug/L	<0.19	<0.19	<0.19	<0.19	<0.19	<0.033	<0.033	0.9	--	<0.033	<0.12	<0.13	--	<0.27	<0.27	<0.27
Lithium	ug/L	52.4	57.8	48.5	61	70.7	52.1	44.1	51	--	63.8	34.3	82.4	35.9	52	38	47
Mercury	ug/L	<0.046	<0.039	<0.039	<0.039	<0.055	<0.046	<0.046	<0.046	--	<0.09	--	<0.09	--	<0.1	--	0.11
Molybdenum	ug/L	101	105	118	131	121	90.6	67.4	66.8	--	126	74.9	113	47.4	58	47	45
Selenium	ug/L	<0.18	<0.18	0.23	0.24	0.24	0.31	0.19	0.26	--	0.24	0.21	0.26	--	<1	<1	<1
Thallium	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	0.068	<0.036	0.12	--	<0.036	--	<0.099	--	<0.27	--	<0.26
Total Radium	pCi/L	1.26	0.659	1.1	1.16	0.455	0.742	1.29	0.752	--	0.589	0.725	0.706	--	0.408	0.781	0.573
Radium-226	pCi/L	0	0.0649	0.22	0.458	0.067	0.48	0.928	0.404	--	0.405	0.151	0.233	--	0.116	0.353	0.3
Radium-228	pCi/L	1.26	0.594	0.881	0.704	0.388	0.262	0.362	0.348	--	0.184	0.574	0.473	--	0.292	0.428	0.272
Field Oxidation Potential	mV	-309.5	-153	-301	-251.4	-274.8	-260.1	-160.6	-231.3	5.9	-273	-202	-100.2	-73.8	-216.7	-157.5	52.4
Field Specific Conductance	umhos/cm	766	1455	1840	1712	1634	1427	512.5	971	756	906	836	780	460	658	934	1087
Field Temperature	deg C	13.9	14	14.4	15.3	15	14.1	14.3	14.8	15.1	13.5	18.1	17.41	13.87	12.96	15.64	14.6
Groundwater Elevation	feet	521.78	521.28	521.37	527.57	525.62	522.87	522.9	519.23	522.32	525.85	519.81	528.82	522.8	528.27	--	524.02
Oxygen, Dissolved	mg/L	0.04	1.55	4.79	0.43	0.11	0.11	0.17	0.03	0.1	1.4	0.09	0.23	2.11	0.39	0.28	0.15
Turbidity	NTU	1.43	1.26	0.01	0.3	0	0.61	0.23	0.26	1.89	2.84	4.26	1.36	9.28	6.22	1.18	18.18

Single Location

Name: IPL - Burlington

Location ID: MW-305
Number of Sampling Dates: 15

Parameter Name	Units	4/20/2016	6/6/2016	8/17/2016	10/3/2016	1/10/2017	4/3/2017	6/13/2017	8/16/2017	10/16/2017	5/9/2018	8/13/2018	10/10/2018	4/3/2019	10/11/2019	6/3/2020
Boron	ug/L	1990	2040	1750	1730	1910	1880	2180	1950	2480	2000	2400	2040	2000	2100	2200
Calcium	mg/L	116	119	95.1	93.1	88.8	82.8	96.3	80.2	92.2	82.5	103	93.2	83	90	120
Chloride	mg/L	34.8	32.9	34.5	32.3	34.8	34.2	37	34.3	35.8	34.8	34.8	34.9	33	33	36
Fluoride	mg/L	0.45	0.28	0.3	0.43	0.34	0.42	0.43	0.48	0.43	0.48	0.45	0.44	0.75	0.37	0.45
pH at 25 Degrees C	Std. Units	7.1	7.2	7	7.4	7.8	7.5	7.1	7.3	7.2	7.5	7.5	7.3	7.4	7.5	7.3
Field pH	Std. Units	7.25	7.75	7.54	7.63	7.48	7.55	7.74	7	7.78	7.72	7.81	7.29	7.8	7.36	7.12
Sulfate	mg/L	35.7	68	26.9	38.1	19.2	10.2	35	13.4	24.6	11.7	24.8	19.6	10	8.8	33
Total Dissolved Solids	mg/L	574	590	502	467	455	410	532	435	437	441	542	490	470	490	640
Antimony	ug/L	0.11	0.11	<0.058	0.082	<0.058	<0.026	<0.026	0.13	--	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58
Arsenic	ug/L	0.91	0.4	0.33	0.61	0.23	0.32	0.22	0.32	--	0.28	0.39	0.44	<0.75	<0.75	<0.88
Barium	ug/L	231	242	208	190	208	178	231	186	--	173	219	197	160	180	230
Beryllium	ug/L	<0.08	<0.08	<0.08	<0.08	<0.08	0.038	0.013	0.018	--	<0.012	<0.12	<0.089	<0.27	<0.27	<0.27
Cadmium	ug/L	<0.029	<0.029	<0.029	<0.029	<0.029	<0.018	<0.018	<0.018	--	<0.018	<0.07	<0.033	<0.077	<0.039	<0.039
Chromium	ug/L	0.43	0.36	0.57	0.76	0.54	0.29	0.27	0.43	--	0.25	0.21	0.27	<0.98	<0.98	<1.1
Cobalt	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	0.14	0.2	0.15	--	0.14	<0.15	0.17	0.16	0.13	0.18
Lead	ug/L	0.22	<0.19	<0.19	<0.19	<0.19	0.19	0.11	0.24	--	0.034	<0.12	0.2	<0.27	<0.27	<0.27
Lithium	ug/L	24	29.8	17.2	25.2	28.5	25	26	26.6	--	27.8	33.6	27.6	29	26	28
Mercury	ug/L	<0.046	<0.039	<0.039	<0.039	<0.055	<0.046	<0.046	<0.046	--	<0.09	--	<0.09	<0.1	--	0.12
Molybdenum	ug/L	0.6	0.79	1.2	1.2	0.76	0.89	1.1	1.3	--	0.87	1	0.72	<1.1	<1.1	<1.1
Selenium	ug/L	<0.18	<0.18	0.19	<0.18	<0.18	0.19	<0.086	0.18	--	0.24	0.16	0.16	<1	<1	<1
Thallium	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.036	<0.036	0.15	--	<0.036	--	<0.099	<0.27	--	<0.26
Total Radium	pCi/L	1.73	1.58	1.55	1.54	1.31	0.73	1.35	1.14	--	2.11	1.78	1.22	0.519	0.441	0.759
Radium-226	pCi/L	0.125	0.529	0.143	0.43	0.467	0.128	0.551	0.454	--	0.992	0.411	0.423	0.154	0.256	0.248
Radium-228	pCi/L	1.6	1.05	1.41	1.11	0.847	0.602	0.795	0.683	--	1.12	1.37	0.8	0.365	0.185	0.511
Field Oxidation Potential	mV	-142	-120	-133.3	-133.6	-119.8	-145.1	-80.8	-94.7	44.9	-146.8	-134	-140	-133.5	-132.9	39.8
Field Specific Conductance	umhos/cm	807	1919	1611	1328	1371	1195	624	972	759	733	901	846	733	795	972
Field Temperature	deg C	14.9	14.9	15	15.1	14.7	14.9	15.5	15.4	15.1	15.2	16.3	16.2	14.47	14.29	15.9
Groundwater Elevation	feet	521.96	521.48	521.46	527.71	525.74	523.03	522.78	519.93	522.48	526.06	520.29	528.97	528.36	--	524.12
Oxygen, Dissolved	mg/L	0.13	1.18	0.92	0.44	0.16	0.13	0.09	0.11	0.14	1.4	0.35	0.2	0.59	0.2	0.14
Turbidity	NTU	10.6	1.79	0.41	1.15	0.46	1.88	0.89	0.25	0.71	0.64	3.85	4.94	3.88	3.02	13.46

Single Location

Name: IPL - Burlington

Location ID: MW-306
Number of Sampling Dates: 16

Parameter Name	Units	4/21/2016	6/6/2016	8/17/2016	10/3/2016	1/10/2017	4/4/2017	6/13/2017	8/16/2017	10/16/2017	5/9/2018	8/14/2018	10/10/2018	3/11/2019	4/3/2019	10/11/2019	6/4/2020
Boron	ug/L	3460	3340	3300	3340	3630	3770	3350	3700	3680	3480	3430	3350	--	2900	3100	3200
Calcium	mg/L	37.5	38.1	41.2	40.8	37.5	40.3	34.5	38.9	35.3	32	33.5	34.6	--	37	38	41
Chloride	mg/L	22.9	22.6	20.6	21.1	20.6	20.2	20.6	20.6	20.6	20.3	20.6	20.9	--	21	20	21
Fluoride	mg/L	0.093	<0.073	0.03	0.075	0.052	<0.1	<0.1	<0.1	0.15	0.12	0.1	<0.19	--	0.36	<0.23	<0.23
pH at 25 Degrees C	Std. Units	9.9	10.2	6.1	6.8	7.1	6.8	10.2	6.8	9.7	6.5	10	6	--	6	10.5	10.3
Field pH	Std. Units	10.4	10.36	6.37	6.5	6.33	6.29	11.25	6.59	10.66	6.8	10.33	6.04	6.27	6.69	10.53	10.48
Sulfate	mg/L	152	132	135	137	123	120	126	93.4	97.5	107	111	121	--	110	110	120
Total Dissolved Solids	mg/L	333	321	348	333	307	302	305	312	301	396	303	289	--	320	290	320
Antimony	ug/L	1.2	1.2	1	1.2	1.3	1.2	1.4	0.92	--	1.2	1.4	1.2	--	1.1	1.2	1.1
Arsenic	ug/L	56.6	47.4	43.9	46.4	53.4	50.5	48.1	43.2	--	52.6	48	50.6	--	50	46	50
Barium	ug/L	21.2	18.2	18.8	15.5	14.4	14.8	14.1	14.3	--	13.6	15.5	14.8	--	14	14	16
Beryllium	ug/L	<0.08	<0.08	<0.08	<0.08	<0.08	0.024	0.054	<0.012	--	<0.012	0.14	<0.089	--	<0.27	<0.27	<0.27
Cadmium	ug/L	<0.029	<0.029	<0.029	<0.029	<0.029	<0.018	0.036	<0.018	--	0.029	0.18	<0.033	--	<0.077	<0.039	<0.039
Chromium	ug/L	<0.34	<0.34	0.4	<0.34	0.45	0.49	0.31	0.43	--	0.24	0.25	0.18	--	<0.98	<0.98	<1.1
Cobalt	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	0.034	0.046	0.054	--	0.035	0.18	<0.062	--	<0.091	<0.091	<0.091
Lead	ug/L	0.28	<0.19	<0.19	<0.19	0.19	0.16	0.25	0.3	--	0.26	0.69	0.37	--	<0.27	0.44	0.33
Lithium	ug/L	33.5	37.9	39.5	35.9	44.1	41.2	41.4	46.8	--	36.6	46.8	41.4	39.2	45	46	43
Mercury	ug/L	<0.046	<0.039	<0.039	<0.039	<0.055	<0.046	<0.046	<0.046	--	<0.09	--	<0.09	--	<0.1	--	0.1
Molybdenum	ug/L	95.7	84.1	80.9	83.7	88.9	87.4	80.4	94.4	--	84.7	82.9	83.5	--	78	84	86
Selenium	ug/L	0.66	0.54	0.81	0.46	0.55	0.48	0.74	0.52	--	0.66	0.97	0.6	--	<1	<1	<1
Thallium	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.036	<0.036	0.15	--	<0.036	--	<0.099	--	<0.27	--	<0.26
Total Radium	pCi/L	1.28	0.858	0.208	0.0727	0.744	1.19	0.254	1.03	--	0.482	1.04	1.1	--	0.165	0.526	0.0769
Radium-226	pCi/L	0.438	0.144	0	-0.143	0.0633	0.457	0.157	0.424	--	0.174	0.397	0.383	--	0.0333	0.21	0.0516
Radium-228	pCi/L	0.841	0.714	0.208	0.0727	0.681	0.731	0.0974	0.604	--	0.308	0.64	0.712	--	0.132	0.316	0.0253
Field Oxidation Potential	mV	-127.8	-181	-155.5	-96.8	-26.7	-64.7	-151	-52.5	286.2	-104.3	-265	58.1	-88.9	-92.8	-165.1	59
Field Specific Conductance	umhos/cm	398	977	1000	874	864	823	331.7	662	447.9	354.2	447	478	343	4711	473	482
Field Temperature	deg C	14.5	14.4	14.8	14.8	14.4	14.5	15.8	14.9	14.8	14.7	15.9	17.25	14.27	13.44	14.28	14.4
Groundwater Elevation	feet	521.74	521.43	521.53	527.67	525.67	523.07	522.87	519.82	522.72	526	520.14	528.95	523.21	528.4	--	524.45
Oxygen, Dissolved	mg/L	0.11	0.57	1.91	0.14	0.06	0.12	0.22	0.03	0.37	0.05	0.3	0.38	0.8	0.69	0.21	0.16
Turbidity	NTU	0.4	0.1	0.4	0.97	0.19	0.14	0.81	0.1	0.35	0.71	2.88	2.67	0.56	0.81	1.84	15.96

Single Location

Name: IPL - Burlington

Location ID: MW-307
Number of Sampling Dates: 16

Parameter Name	Units	4/20/2016	6/6/2016	8/17/2016	10/3/2016	1/10/2017	4/4/2017	6/13/2017	8/16/2017	10/16/2017	5/9/2018	8/14/2018	10/10/2018	3/11/2019	4/3/2019	10/11/2019	6/4/2020
Boron	ug/L	3720	3760	3720	3880	3960	4050	3740	3780	3920	3910	4090	3720	--	3400	3700	3600
Calcium	mg/L	31.9	30.8	31.3	34.1	31.3	32.3	28.1	29.8	31.3	27.3	27.2	27.6	--	29	31	37
Chloride	mg/L	23.5	22.6	21.4	21.6	21.3	20.9	21.3	20.7	20.8	20.1	20.1	21.6	--	21	19	21
Fluoride	mg/L	0.099	<0.073	0.032	0.079	0.057	<0.1	<0.1	<0.1	0.13	0.11	0.094	<0.19	--	0.51	<0.23	<0.23
pH at 25 Degrees C	Std. Units	9.8	10	9.8	10.1	9.6	9.8	9.8	9.8	9.8	9.9	9.9	9.9	--	10	10.2	10
Field pH	Std. Units	10.28	10.19	10.6	10.5	10.82	10.94	10.74	10.8	10.46	10.3	10.12	9.88	9.71	10.39	10.14	10.03
Sulfate	mg/L	183	150	160	161	145	135	136	130	126	119	119	143	--	120	130	180
Total Dissolved Solids	mg/L	408	385	386	374	355	354	353	356	341	347	340	336	--	420	340	390
Antimony	ug/L	0.46	0.62	0.48	0.64	0.53	0.48	0.48	0.54	--	0.5	0.58	0.62	--	<0.53	<0.53	<0.58
Arsenic	ug/L	53	57.4	57.1	59.2	59.2	56.2	55.8	52.8	--	54.3	52.3	52.8	--	43	47	47
Barium	ug/L	38.3	42.2	38.7	38.4	34.7	33.4	33	31.1	--	32.3	29	31.1	--	29	31	36
Beryllium	ug/L	<0.08	<0.08	<0.08	<0.08	<0.08	0.033	<0.012	<0.012	--	<0.012	<0.12	<0.089	--	<0.27	<0.27	<0.27
Cadmium	ug/L	<0.029	<0.029	<0.029	<0.029	<0.029	<0.018	<0.018	0.023	--	0.12	<0.07	0.068	--	<0.077	<0.039	0.044
Chromium	ug/L	<0.34	0.84	0.5	0.62	<0.34	0.19	0.24	0.33	--	0.27	0.36	0.15	--	<0.98	<0.98	<1.1
Cobalt	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	0.037	0.042	0.034	--	0.033	<0.15	<0.062	--	<0.091	<0.091	<0.091
Lead	ug/L	0.48	1.1	0.36	0.36	0.45	0.43	0.43	0.46	--	0.39	0.43	0.49	--	0.37	0.41	<0.27
Lithium	ug/L	43.1	45.6	42.4	45.1	49.6	48.4	42.2	47.5	--	47.8	56.1	45.4	50.7	50	48	48
Mercury	ug/L	<0.046	<0.039	<0.039	<0.039	<0.055	0.047	<0.046	<0.046	--	<0.09	--	<0.09	--	<0.1	--	0.12
Molybdenum	ug/L	146	155	142	150	154	154	155	152	--	154	155	159	156	100	130	130
Selenium	ug/L	0.47	0.45	0.46	0.45	0.44	0.42	0.46	0.42	--	0.36	0.41	0.36	--	<1	<1	<1
Thallium	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.036	<0.036	0.18	--	<0.036	--	<0.099	--	<0.27	--	<0.26
Total Radium	pCi/L	1.6	0.194	0.882	0.552	0	0.651	0.85	0.673	--	0.0587	0.415	1.43	--	0.447	0.232	0.277
Radium-226	pCi/L	0.153	-0.064	0.068	0.197	-0.075	-0.156	0.735	0.393	--	0.0587	0	0.988	--	0.0752	0.218	0.0806
Radium-228	pCi/L	1.45	0.258	0.814	0.355	-0.0697	0.651	0.115	0.28	--	-0.024	0.415	0.439	--	0.372	0.0141	0.197
Field Oxidation Potential	mV	-201.7	-168	-212.1	-289.4	-253.6	-287.1	-177.1	-168.9	-78.9	-168.6	-221	-87.3	-78.3	-167.8	-126.3	60.2
Field Specific Conductance	umhos/cm	480.2	1142	1064	958	940	901	368.3	735	485.7	499.9	512	497	367	500	536	586
Field Temperature	deg C	14.2	14.1	14.2	14.6	14.4	14.4	14.9	14.6	14.7	14.4	15.6	15.64	14.36	13.56	14.37	14.8
Groundwater Elevation	feet	522.38	521.75	521.91	527.81	525.81	523.14	523.17	520.16	522.55	526.06	520.46	529.08	523.49	528.63	--	524.62
Oxygen, Dissolved	mg/L	0.08	0.6	6.01	0.29	0.11	0.28	0.12	0.19	0.18	1.1	0.49	0.22	1.07	0.68	0.24	0.3
Turbidity	NTU	1.54	0.46	0.6	1.4	0.6	0.14	3.11	1.98	0.32	1.87	5.09	1.85	1.05	3.1	3.23	14.33

Single Location

Name: IPL - Burlington

Location ID: MW-307A

Number of Sampling Dates: 1

Parameter Name	Units	9/9/2020
Boron	ug/L	3900
Calcium	mg/L	10
Chloride	mg/L	34
Fluoride	mg/L	<0.23
Field pH	Std. Units	7.83
Sulfate	mg/L	110
Total Dissolved Solids	mg/L	370
Antimony	ug/L	<0.51
Arsenic	ug/L	<0.88
Barium	ug/L	45

Location ID: MW-307A

Number of Sampling Dates: 1

Parameter Name	Units	9/9/2020
Beryllium	ug/L	<0.27
Cadmium	ug/L	0.058
Chromium	ug/L	<1.1
Cobalt	ug/L	0.11
Lead	ug/L	0.69
Lithium	ug/L	6.8
Mercury	ug/L	<0.1
Molybdenum	ug/L	110
Selenium	ug/L	<1
Thallium	ug/L	<0.26
Field Oxidation Potential	mV	-154.2
Field Specific Conductance	umhos/cm	585
Field Temperature	deg C	14.4

Location ID: MW-307A

Number of Sampling Dates: 1

Parameter Name	Units	9/9/2020
Groundwater Elevation	feet	519.97
Turbidity	NTU	0
pH	Std. Units	8

Single Location

Name: IPL - Burlington

Location ID: MW-308
Number of Sampling Dates: 16

Parameter Name	Units	4/21/2016	6/6/2016	8/17/2016	10/3/2016	1/10/2017	4/4/2017	6/13/2017	8/16/2017	10/17/2017	5/8/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/4/2020
Boron	ug/L	4960	4980	4870	4760	4980	5160	4680	4910	4850	5030	5070	4710	--	4300	4500	4700
Calcium	mg/L	39.8	36.8	35.1	33.5	33.2	34.2	30.1	32.3	32.6	28.7	28.7	28.5	--	32	30	34
Chloride	mg/L	72.3	65.7	53.1	47.8	43.5	42.6	40.6	39.8	38.2	36.2	36.7	35.9	--	38	40	58
Fluoride	mg/L	0.16	0.095	0.078	0.13	0.084	0.11	0.12	0.14	0.17	0.17	0.16	<0.19	--	0.37	<0.23	0.37
pH at 25 Degrees C	Std. Units	9.4	9.6	9.3	9.7	9.4	9.2	9.5	9.4	9.4	9.4	9.4	9.5	--	9.6	9.9	9.6
Field pH	Std. Units	9.77	9.76	9.95	10.17	10.21	10.34	9.99	10.15	9.75	9.75	9.86	9.82	7.72	9.97	9.42	9.65
Sulfate	mg/L	222	187	180	194	192	175	188	181	177	164	167	193	--	170	160	190
Total Dissolved Solids	mg/L	577	548	541	495	474	494	501	483	472	494	468	440	--	490	400	470
Antimony	ug/L	0.29	0.34	0.22	0.38	0.33	0.28	0.32	0.3	--	0.32	0.32	0.36	--	<0.53	<0.53	<0.58
Arsenic	ug/L	83.8	80.5	84.2	82.6	86.4	83.1	80.3	77.9	--	79.1	82.5	79.5	--	78	72	76
Barium	ug/L	130	110	110	89.8	90.6	85.1	81.5	76.2	--	64.3	67.1	66.5	--	70	70	66
Beryllium	ug/L	<0.08	<0.08	<0.08	<0.08	<0.08	0.017	<0.012	<0.012	--	<0.012	<0.12	<0.089	--	<0.27	<0.27	<0.27
Cadmium	ug/L	<0.029	<0.029	<0.029	0.097	0.034	<0.018	0.035	<0.018	--	0.02	<0.07	0.058	--	<0.077	<0.039	0.044
Chromium	ug/L	0.46	0.41	0.52	<0.34	0.37	0.22	0.16	0.38	--	0.25	<0.19	0.16	--	<0.98	<0.98	<1.1
Cobalt	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	0.06	0.068	0.069	--	0.057	<0.15	0.074	--	<0.091	<0.091	<0.091
Lead	ug/L	0.33	<0.19	<0.19	0.28	0.27	0.21	0.34	0.33	--	0.25	0.27	0.45	--	<0.27	<0.27	0.4
Lithium	ug/L	45.6	45.8	41.5	41.2	47	46.9	42.4	44.1	--	46	52	43.6	48.9	50	52	48
Mercury	ug/L	<0.046	<0.039	<0.039	<0.039	<0.055	0.047	<0.046	<0.046	--	<0.09	--	<0.09	--	<0.1	--	0.13
Molybdenum	ug/L	153	139	133	138	140	140	136	137	--	140	140	145	135	110	120	120
Selenium	ug/L	0.69	0.47	0.58	0.45	0.68	0.4	0.3	0.47	--	0.31	0.43	0.4	--	<1	<1	<1
Thallium	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.036	<0.036	<0.036	--	<0.036	--	<0.099	--	<0.27	--	<0.26
Total Radium	pCi/L	0.712	1.22	0.376	0.549	0	0.854	0.881	0.229	--	0.283	0.0726	0.334	--	0.328	0.288	0.268
Radium-226	pCi/L	0.0744	0	0.0777	0.312	0	0.213	0.4	0.063	--	0.182	0.0726	0.275	--	0.0363	0.202	0.109
Radium-228	pCi/L	0.638	1.22	0.298	0.237	-0.059	0.641	0.481	0.166	--	0.101	-0.068	0.0585	--	0.291	0.0862	0.159
Field Oxidation Potential	mV	-77.2	-149	-213.7	-239.6	-163.8	-300.6	-162.3	-139.8	-109.4	-158.2	-238	-201	-60.7	-142.3	-82.6	28
Field Specific Conductance	umhos/cm	712	1678	1533	1306	1303	1258	514.6	1039	689	698	710	709	500	681	671	713
Field Temperature	deg C	14.2	14.2	14.3	14.6	13.7	14.1	14.9	14.5	14.6	14.4	15.4	15.3	14.06	14.04	14.64	15.4
Groundwater Elevation	feet	521.93	521.43	521.56	527.62	525.65	523.07	522.9	519.8	522.46	525.62	520.22	528.98	523.13	528.39	--	524.1
Oxygen, Dissolved	mg/L	0.09	0.81	0.16	0.55	0.11	0.16	0.2	0.21	0.09	1.5	0.11	0.2	2.57	1.16	0.21	0.23
Turbidity	NTU	1.83	0.42	0.34	0.73	1.27	0.43	1.56	0.61	0.6	1.26	4.63	1.35	1.68	1.66	2.93	13.38

Single Location

Name: IPL - Burlington

Location ID: MW-309
Number of Sampling Dates: 15

Parameter Name	Units	4/21/2016	6/7/2016	8/16/2016	10/3/2016	1/10/2017	4/4/2017	6/13/2017	8/16/2017	10/17/2017	5/8/2018	8/14/2018	10/10/2018	4/4/2019	10/11/2019	6/3/2020
Boron	ug/L	5270	5590	5180	5140	4880	3800	4070	4310	4400	4720	4930	4720	4200	4300	4400
Calcium	mg/L	118	100	99.2	126	141	156	118	130	101	83.6	74.1	72.4	73	68	82
Chloride	mg/L	145	152	126	117	104	82.7	89.5	92.5	85.4	112	111	105	100	74	84
Fluoride	mg/L	0.57	0.36	0.35	0.39	0.39	0.41	0.5	0.4	0.47	0.4	0.43	0.4	0.71	0.29	0.58
pH at 25 Degrees C	Std. Units	7	7	7	7.2	7.3	7.4	6.9	7.2	7	7.4	7.3	7.1	7.1	7.2	7.2
Field pH	Std. Units	7.33	7.43	7.66	7.66	7.37	7.31	7.1	7.62	8.5	7.25	7.39	7.46	7.45	7.19	7.09
Sulfate	mg/L	49	51.2	100	104	127	198	171	136	149	107	98.9	111	78	160	180
Total Dissolved Solids	mg/L	768	728	726	772	839	955	841	859	671	688	668	650	650	610	730
Antimony	ug/L	0.087	0.12	<0.058	0.09	<0.058	0.039	0.03	0.051	--	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58
Arsenic	ug/L	31.5	27.3	29.3	31.5	34.5	30	36.2	34.6	--	28.2	33.3	35.6	30	34	34
Barium	ug/L	384	337	316	364	362	264	256	274	--	154	180	194	130	180	260
Beryllium	ug/L	<0.08	<0.08	<0.08	<0.08	<0.08	0.037	0.012	<0.012	--	0.012	<0.12	<0.089	<0.27	<0.54	<0.27
Cadmium	ug/L	<0.029	<0.029	<0.029	<0.029	<0.029	<0.018	0.021	<0.018	--	0.021	<0.07	<0.033	<0.077	<0.039	<0.039
Chromium	ug/L	0.38	0.35	0.53	<0.34	0.4	0.23	0.18	0.49	--	0.32	0.22	0.18	<0.98	<0.98	<1.1
Cobalt	ug/L	2.1	1.2	0.98	1.1	1.7	6.5	2.9	1.3	--	4.9	0.82	0.68	1.3	0.52	0.57
Lead	ug/L	<0.19	<0.19	<0.19	<0.19	<0.19	<0.033	0.12	0.26	--	0.045	<0.12	<0.13	<0.27	<0.27	<0.27
Lithium	ug/L	<4.9	<4.9	<4.9	<4.9	<4.9	5	<2.9	6.3	--	<4.6	<4.6	<4.6	3.3	<5.4	2.4
Mercury	ug/L	<0.046	<0.039	<0.039	<0.039	<0.055	<0.046	<0.046	<0.046	--	<0.09	--	<0.09	<0.1	--	<0.1
Molybdenum	ug/L	30.7	31.1	43.5	49.1	44.8	41.5	60.8	67.5	--	43.4	52.8	71.8	47	90	87
Selenium	ug/L	0.39	0.25	0.24	0.31	0.25	0.44	0.35	0.34	--	0.3	0.31	0.29	<1	<1	<1
Thallium	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.036	<0.036	<0.036	--	<0.036	--	<0.099	<0.27	--	<0.26
Total Radium	pCi/L	2.55	2.28	1.74	1.38	0.455	1.76	0.846	1.09	--	0.218	0.96	1.05	0.42	0.596	0.296
Radium-226	pCi/L	0.991	0.561	0.67	0.694	0.65	0.573	0.292	0.615	--	-0.061	0.28	0.127	0.126	0.274	0.182
Radium-228	pCi/L	1.56	1.72	1.07	0.69	0.39	1.19	0.554	0.47	--	0.218	0.68	0.919	0.295	0.322	0.114
Field Oxidation Potential	mV	-138.9	-121	-150.9	-176.2	-131.4	-138	-60.7	-112.8	-31	-139.2	-143	-53.5	-99.4	-165.6	37
Field Specific Conductance	umhos/cm	1034	2369	228.5	2265	2502	2528	936	1853	1058	813	1093	1038	997	1040	1086
Field Temperature	deg C	13.4	13.4	13.8	14.6	14.3	13.9	14.2	14.6	14.6	13.5	14.2	15.67	12.6	13.73	14.8
Groundwater Elevation	feet	522.09	521.39	521.7	527.57	525.57	523.1	522.91	519.93	522.67	525.54	520.22	528.93	528.4	--	524.06
Oxygen, Dissolved	mg/L	0.1	0.78	2.36	0.54	0.11	0.2	0.15	0.2	0.08	0.05	0.14	0.18	0.51	0.21	0.23
Turbidity	NTU	3.93	0.59	0.58	0.72	5.84	15.11	4.62	4.61	3.08	6.49	12.67	34.45	20.1	8.93	18.88

Single Location

Name: IPL - Burlington

Location ID: MW-310
Number of Sampling Dates: 15

Parameter Name	Units	4/21/2016	6/7/2016	8/16/2016	10/3/2016	1/9/2017	4/4/2017	6/12/2017	8/16/2017	10/16/2017	5/8/2018	8/14/2018	10/10/2018	4/4/2019	10/11/2019	6/2/2020
Boron	ug/L	437	422	326	400	413	503	2210	365	305	217	256	268	560	380	500
Calcium	mg/L	166	181	140	167	145	180	116	139	105	104	102	107	120	120	130
Chloride	mg/L	154	196	96.9	143	113	187	94.7	121	38.3	24.4	33.8	67.1	88	59	87
Fluoride	mg/L	0.39	0.28	0.29	0.34	0.33	0.26	0.32	0.32	0.39	0.33	0.39	0.4	0.55	0.34	0.65
pH at 25 Degrees C	Std. Units	7.1	7	7	7.2	7.2	7.3	6.9	7.1	7.1	7.4	7.3	7.1	7	7.2	7.1
Field pH	Std. Units	7.37	7.21	7.7	7.71	7.38	7.5	7.3	7.5	7.92	7.46	7.44	7.2	7.84	6.95	7.3
Sulfate	mg/L	53.1	47.7	54	62.6	48.5	34.3	101	41.3	35.1	28.8	27.2	37.9	21	51	100
Total Dissolved Solids	mg/L	879	1040	703	743	653	853	625	760	445	462	472	512	600	410	590
Antimony	ug/L	<0.058	0.12	<0.058	0.099	<0.058	0.032	0.048	0.1	--	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58
Arsenic	ug/L	60.6	60.2	64.1	74	72.6	79.8	64	68.2	--	57.8	56.2	62.1	65	61	55
Barium	ug/L	813	829	589	734	605	825	586	665	--	403	398	450	560	500	550
Beryllium	ug/L	<0.08	<0.08	<0.08	<0.08	<0.08	0.019	<0.012	<0.012	--	<0.012	<0.12	<0.089	<0.27	<0.27	<0.27
Cadmium	ug/L	<0.029	<0.029	<0.029	<0.029	<0.029	<0.018	0.025	<0.018	--	<0.018	<0.07	<0.033	<0.077	<0.039	<0.039
Chromium	ug/L	<0.34	<0.34	0.85	0.5	0.45	0.19	0.2	0.52	--	0.16	<0.19	0.082	<0.98	<0.98	<1.1
Cobalt	ug/L	2.6	2.7	1.8	2	1.6	1.9	1.4	1.8	--	1.2	1.4	1.4	1.9	1.9	2.3
Lead	ug/L	<0.19	<0.19	<0.19	<0.19	<0.19	<0.033	0.081	0.64	--	0.044	<0.12	<0.13	<0.27	<0.27	<0.27
Lithium	ug/L	<4.9	<4.9	<9.8	<4.9	<4.9	<2.9	<2.9	7.7	--	<4.6	5.3	<4.6	<2.7	<2.7	<2.3
Mercury	ug/L	<0.046	<0.039	<0.039	<0.039	<0.055	<0.046	<0.046	<0.046	--	<0.09	--	<0.09	<0.1	--	<0.1
Molybdenum	ug/L	5.1	3.9	4.4	4.8	4.4	3.4	10	4.1	--	4.2	4	4.6	5.2	6	5.8
Selenium	ug/L	<0.18	<0.18	<0.18	<0.18	<0.18	0.24	0.18	0.2	--	0.14	<0.16	0.19	<1	<1	<1
Thallium	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.036	<0.036	0.35	--	<0.036	--	<0.099	<0.27	--	<0.26
Total Radium	pCi/L	2.41	1.28	1.99	1.34	0.941	3.17	1.7	2.21	--	0.755	1.55	2.56	1.19	0.49	0.844
Radium-226	pCi/L	0.951	0.839	0.644	0.796	0.527	0.175	0.505	0.793	--	0	0.616	1.1	0.471	0.473	0.457
Radium-228	pCi/L	1.46	0.437	1.35	0.54	0.414	2.99	1.19	1.42	--	0.755	0.938	1.46	0.724	0.0174	0.387
Field Oxidation Potential	mV	-125.4	-122	-172.9	-184	-161.2	-175.4	-101.1	102.8	-63.6	-198.8	-194	-166	-175.8	-189.7	38.6
Field Specific Conductance	umhos/cm	1082	3170	2224	2295	2116	2528	742	1783	791	594.6	840	938	1034	961	881
Field Temperature	deg C	11.7	12.2	15.1	16.6	14.3	12	13.5	15.4	16.6	11.1	15	17	10.8	15.88	12.8
Groundwater Elevation	feet	525.43	524.13	524.84	527.58	525.78	525.52	524.94	523.89	525.49	525.79	523.69	529	528.62	--	525.36
Oxygen, Dissolved	mg/L	0.19	0.98	2.4	0.43	0.19	0.2	0.13	0.21	0.16	0.14	0.05	0.1	1.12	0.28	0.13
Turbidity	NTU	3	0.2	0.83	4.23	4.64	2.23	2.55	1.2	2.86	12.81	3.11	0	16.7	5.23	17.82

Single Location

Name: IPL - Burlington

Location ID:	MW-310A	
Number of Sampling Dates: 1		
Parameter Name	**Units**	**9/9/2020**
Boron	ug/L	2200
Calcium	mg/L	150
Chloride	mg/L	18
Fluoride	mg/L	0.27
Field pH	Std. Units	7.33
Sulfate	mg/L	100
Total Dissolved Solids	mg/L	570
Antimony	ug/L	1.1
Arsenic	ug/L	15
Barium	ug/L	290

Location ID: MW-310A

Number of Sampling Dates: 1

Parameter Name	Units	9/9/2020
Beryllium	ug/L	2.3
Cadmium	ug/L	0.69
Chromium	ug/L	5.4
Cobalt	ug/L	28
Lead	ug/L	20
Lithium	ug/L	32
Mercury	ug/L	<0.1
Molybdenum	ug/L	19
Selenium	ug/L	1.5
Thallium	ug/L	<0.26
Field Oxidation Potential	mV	145.3
Field Specific Conductance	umhos/cm	1026
Field Temperature	deg C	14.2

Location ID:	MW-310A	
Number of Sampling Dates: 1		
Parameter Name	**Units**	**9/9/2020**
Groundwater Elevation	feet	509.16
Turbidity	NTU	714.3
pH	Std. Units	7.7

Single Location

Name: IPL - Burlington

Location ID: MW-311
Number of Sampling Dates: 15

Parameter Name	Units	4/21/2016	6/7/2016	8/16/2016	10/3/2016	1/9/2017	4/4/2017	6/12/2017	8/16/2017	10/16/2017	5/8/2018	8/14/2018	10/10/2018	4/4/2019	10/11/2019	6/2/2020
Boron	ug/L	1810	2070	2320	2950	2160	2400	2130	360	2810	2200	2580	2820	1800	2800	2500
Calcium	mg/L	200	164	158	150	164	176	158	139	145	173	156	130	200	150	190
Chloride	mg/L	125	75.4	77.4	62.7	78.7	83.3	81.1	45	50.9	79.9	69.9	54	110	65	120
Fluoride	mg/L	0.38	0.27	0.28	0.35	0.32	0.27	0.36	0.36	0.36	0.31	0.36	0.35	0.41	0.37	0.64
pH at 25 Degrees C	Std. Units	7	7.2	7.1	7.2	7.5	7.1	7	7.2	7.4	7.4	7.2	7.1	7	7.2	7
Field pH	Std. Units	7.33	7.28	7.63	7.59	7.24	7.51	7.3	7.05	8.27	7.26	7.33	7.49	7.64	7.07	7.1
Sulfate	mg/L	283	179	170	161	179	184	173	112	119	176	144	127	230	130	220
Total Dissolved Solids	mg/L	1060	843	799	694	776	808	803	623	615	864	777	678	980	590	950
Antimony	ug/L	<0.058	0.12	<0.058	0.084	<0.058	<0.026	0.03	0.057	--	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58
Arsenic	ug/L	17.7	12.4	16.4	13	17.6	17.1	15.2	11.6	--	14	15.7	15.2	19	18	19
Barium	ug/L	292	248	232	229	244	240	248	198	--	256	239	214	280	210	300
Beryllium	ug/L	<0.08	<0.08	<0.08	<0.08	<0.08	0.036	0.013	<0.012	--	<0.023	<0.12	<0.089	<0.27	<0.27	<0.27
Cadmium	ug/L	<0.029	<0.029	<0.029	<0.029	<0.029	<0.018	<0.018	<0.018	--	<0.018	<0.07	<0.033	<0.077	<0.039	<0.039
Chromium	ug/L	0.45	0.42	0.51	<0.34	0.35	0.18	0.14	0.32	--	0.2	0.22	0.78	<0.98	<0.98	<1.1
Cobalt	ug/L	0.52	<0.5	<0.5	<0.5	<0.5	0.27	0.35	0.24	--	0.3	0.37	0.57	0.45	0.27	0.81
Lead	ug/L	0.2	<0.19	<0.19	<0.19	<0.19	<0.033	0.32	0.096	--	0.043	0.13	0.48	0.37	<0.27	1.1
Lithium	ug/L	<4.9	<4.9	<9.8	<4.9	<4.9	<2.9	<2.9	3.3	--	<4.6	<4.6	<4.6	<2.7	<2.7	<2.3
Mercury	ug/L	<0.046	<0.039	<0.039	<0.039	<0.055	<0.046	<0.046	<0.046	--	<0.09	--	<0.09	<0.1	--	0.13
Molybdenum	ug/L	10.4	11.7	12.5	14.7	10.9	12.4	11.2	16	--	11.6	13.9	16.3	8.5	15	11
Selenium	ug/L	0.19	<0.18	<0.18	<0.18	0.2	0.17	0.19	0.12	--	0.17	0.18	0.23	<1	<1	<1
Thallium	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.036	<0.036	0.14	--	<0.036	--	<0.099	<0.27	--	<0.26
Total Radium	pCi/L	0.831	1.22	1.19	0.22	1.19	1.13	0.785	1	--	0.987	0.969	0.819	0.815	0.599	0.802
Radium-226	pCi/L	0.207	0.18	0.605	0.149	0.299	0.484	0.445	0.653	--	0.183	0.502	0.245	0.198	0.354	0.324
Radium-228	pCi/L	0.624	1.04	0.581	0.0707	0.886	0.641	0.34	0.349	--	0.804	0.467	0.574	0.617	0.245	0.479
Field Oxidation Potential	mV	-129.9	-69.7	-139	-151.4	-171.4	-157.4	-102.5	-107.1	308.3	-143.3	-158	-62.2	145.8	-163.4	-1.1
Field Specific Conductance	umhos/cm	1173	2425	2304	1833	2126	2059	865	1280	972	1282	1177	1003	1422	1088	1464
Field Temperature	deg C	11.6	11.6	13	14.3	14.3	12.4	12.5	13.7	14.7	11.5	14.8	16.35	11.41	14.19	12.3
Groundwater Elevation	feet	523.72	521.8	522.92	527.34	525.16	524.01	523.55	521.12	523.44	525.08	521.06	528.49	528.2	--	524.05
Oxygen, Dissolved	mg/L	0.08	1.01	0.83	0.51	0.18	0.22	0.21	0.03	0.25	1.6	0.12	0.45	0.78	0.3	0.16
Turbidity	NTU	4.41	1.05	1.74	2.08	1.16	3	4.12	1.15	2.19	1.48	12.3	17.8	10.8	13.4	17.95

Single Location

Name: IPL - Burlington

Location ID: MW-312
Number of Sampling Dates: 3

Parameter Name	Units	6/6/2019	10/10/2019	6/3/2020
Boron	ug/L	6100	6600	6700
Calcium	mg/L	67	71	74
Chloride	mg/L	27	25	36
Fluoride	mg/L	1.1	0.25	0.57
pH at 25 Degrees C	Std. Units	7.5	7.3	7.1
Field pH	Std. Units	6.99	7.19	7.13
Sulfate	mg/L	220	230	200
Total Dissolved Solids	mg/L	540	510	670
Antimony	ug/L	<0.53	<0.53	<0.58
Arsenic	ug/L	14	15	22
Barium	ug/L	160	150	190
Beryllium	ug/L	<0.27	<0.54	<0.27
Cadmium	ug/L	<0.077	0.044	0.095
Chromium	ug/L	<0.98	<0.98	<1.1
Cobalt	ug/L	0.65	0.36	0.67
Lead	ug/L	0.54	<0.27	<0.27
Lithium	ug/L	24	27	22

Location ID: MW-312

Number of Sampling Dates: 3

Parameter Name	Units	6/6/2019	10/10/2019	6/3/2020
Mercury	ug/L	<0.1	--	<0.1
Molybdenum	ug/L	290	280	320
Selenium	ug/L	<1	<1	<1
Thallium	ug/L	<0.27	--	<0.26
Total Radium	pCi/L	0.875	0.438	0.543
Radium-226	pCi/L	0.301	0.433	0.356
Radium-228	pCi/L	0.574	0.00445	0.187
Field Oxidation Potential	mV	-146.4	-163.8	53.3
Field Specific Conductance	umhos/cm	783	785	878
Field Temperature	deg C	14.4	15.6	14.7
Groundwater Elevation	feet	--	--	524.05
Oxygen, Dissolved	mg/L	0.12	8.75	0.17
Turbidity	NTU	2.86	2.56	21.16

Single Location

Name: IPL - Burlington

Location ID: MW-313

Number of Sampling Dates: 3

Parameter Name	Units	6/6/2019	10/10/2019	6/3/2020
Boron	ug/L	7400	8500	8600
Calcium	mg/L	110	120	120
Chloride	mg/L	85	51	83
Fluoride	mg/L	0.33	0.28	0.52
pH at 25 Degrees C	Std. Units	7.4	7.2	7.1
Field pH	Std. Units	6.94	7.06	7.03
Sulfate	mg/L	210	210	230
Total Dissolved Solids	mg/L	700	520	830
Antimony	ug/L	<0.53	<0.53	<0.58
Arsenic	ug/L	5.5	6.3	6.9
Barium	ug/L	510	490	680
Beryllium	ug/L	<0.27	<1.1	<0.27
Cadmium	ug/L	<0.077	<0.039	0.039
Chromium	ug/L	<0.98	<0.98	<1.1
Cobalt	ug/L	0.41	0.32	0.23
Lead	ug/L	<0.27	0.31	<0.27
Lithium	ug/L	43	62	52

Location ID: MW-313

Number of Sampling Dates: 3

Parameter Name	Units	6/6/2019	10/10/2019	6/3/2020
Mercury	ug/L	<0.1	--	0.13
Molybdenum	ug/L	130	110	130
Selenium	ug/L	<1	<1	<1
Thallium	ug/L	<0.27	--	<0.26
Total Radium	pCi/L	0.987	1.7	1.81
Radium-226	pCi/L	0.532	0.968	1.18
Radium-228	pCi/L	0.455	0.736	0.631
Field Oxidation Potential	mV	-141.6	-163.4	50.9
Field Specific Conductance	umhos/cm	1059	1007	1099
Field Temperature	deg C	14.9	16.04	17.2
Groundwater Elevation	feet	--	--	524.02
Oxygen, Dissolved	mg/L	0.07	0.37	0.29
Turbidity	NTU	7.23	11.03	50.81

Single Location

Name: IPL - Burlington

Location ID: MW-313A

Number of Sampling Dates: 1

Parameter Name	Units	9/9/2020
Boron	ug/L	4300
Calcium	mg/L	48
Chloride	mg/L	210
Fluoride	mg/L	<0.23
Field pH	Std. Units	7.6
Sulfate	mg/L	200
Total Dissolved Solids	mg/L	730
Antimony	ug/L	<0.51
Arsenic	ug/L	<0.88
Barium	ug/L	270

Location ID: MW-313A

Number of Sampling Dates: 1

Parameter Name	Units	9/9/2020
Beryllium	ug/L	<0.27
Cadmium	ug/L	<0.049
Chromium	ug/L	<1.1
Cobalt	ug/L	<0.091
Lead	ug/L	<0.11
Lithium	ug/L	13
Mercury	ug/L	<0.1
Molybdenum	ug/L	120
Selenium	ug/L	<1
Thallium	ug/L	<0.26
Field Oxidation Potential	mV	-164.4
Field Specific Conductance	umhos/cm	1243
Field Temperature	deg C	15.3

Location ID: MW-313A		
Number of Sampling Dates: 1		
Parameter Name	**Units**	**9/9/2020**
Groundwater Elevation	feet	515.36
Turbidity	NTU	0
pH	Std. Units	7.7

B3 Most Recent Annual Groundwater Quality Report

2019 Annual Groundwater Monitoring and Corrective Action Report

Burlington Generating Station
Burlington, Iowa

Prepared for:

Alliant Energy

SCS ENGINEERS

25219066.00 | January 31, 2020

2830 Dairy Drive
Madison, WI 53718-6751
608-224-2830

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1.0 INTRODUCTION

This 2019 Annual Groundwater Monitoring and Corrective Action Report was prepared to support compliance with the groundwater monitoring requirements of the Coal Combustion Residuals (CCR) Rule [40 CFR 257.50-107]. Specifically, this report was prepared to fulfill the requirements of 40 CFR 257.90(e). The applicable sections of the Rule are provided below in italics, followed by applicable information relative to the 2019 Annual Groundwater Monitoring and Corrective Action Report for the CCR Units.

This report covers the period of groundwater monitoring from January 1, 2019, through December 31, 2019.

The groundwater monitoring system at the Burlington Generating Station (BGS) impoundments is a multi-unit system. The BGS facility includes four existing CCR units:

- BGS Ash Seal Pond (existing CCR surface impoundment)
- BGS Main Ash Pond (existing CCR surface impoundment)
- BGS Economizer Ash Pond (existing CCR surface impoundment)
- BGS Upper Ash Pond (existing CCR surface impoundment)

The multi-unit system is designed to detect monitored constituents at the waste boundary of the facility as required by 40 CFR 257.91(d). The groundwater monitoring system currently consists of two upgradient monitoring wells, nine downgradient wells at the compliance waste boundary, and two additional downgradient wells.

2.0 §257.90(E) ANNUAL REPORT REQUIREMENTS

Annual groundwater monitoring and corrective action report. *For existing CCR landfills and existing CCR surface impoundments, no later than January 31, 2018, and annually thereafter, the owner or operator must prepare an annual groundwater monitoring and corrective action report. For new CCR landfills, new CCR surface impoundments, and all lateral expansions of CCR units, the owner or operator must prepare the initial annual groundwater monitoring and corrective action report no later than January 31 of the year following the calendar year a groundwater monitoring system has been established for such CCR unit as required by this subpart, and annually thereafter. For the preceding calendar year, the annual report must document the status of the groundwater monitoring and corrective action program for the CCR unit, summarize key actions completed, describe any problems encountered, discuss actions to resolve the problems, and project key activities for the upcoming year. For purposes of this section, the owner or operator has prepared the annual report when the report is placed in the facility's operating record as required by §257.105(h)(1). At a minimum, the annual groundwater monitoring and corrective action report must contain the following information, to the extent available:*

2.1 §257.90(e)(1) Site Map

A map, aerial image, or diagram showing the CCR unit and all background (or upgradient) and downgradient monitoring wells, to include the well identification numbers, that are part of the groundwater monitoring program for the CCR unit;

A map of the site location is provided on **Figure 1**. A map with an aerial image showing the CCR units and all background (or upgradient) and downgradient monitoring wells with identification numbers for the groundwater monitoring program is provided as **Figure 2**.

2.2 §257.90(E)(2) MONITORING SYSTEM CHANGES

Identification of any monitoring wells that were installed or decommissioned during the preceding year, along with a narrative description of why those actions were taken;

Two monitoring wells, MW-312 and MW-313, were installed on May 20 and 21, 2019, to characterize site conditions in accordance with §257.95(g)(1). The monitoring well boring logs and well construction forms were completed for the operating record on September 20, 2019.

2.3 §257.90(E)(3) SUMMARY OF SAMPLING EVENTS

In addition to all the monitoring data obtained under §§257.90 through 257.98, a summary including the number of groundwater samples that were collected for analysis for each background and downgradient well, the dates the samples were collected, and whether the sample was required by the detection monitoring or assessment monitoring programs;

Three groundwater sampling events were completed in 2019. The two semiannual sampling events were completed in April 2019 and October 2019 as required by the assessment monitoring program. Initial samples for the two newly installed monitoring wells were collected in June 2019. The new monitoring wells were also sampled in October 2019, as part of the second semiannual sampling event.

Groundwater samples collected in the April, June, and October 2019 sampling events were analyzed for both Appendix III and Appendix IV constituents. A summary including the number of groundwater samples that were collected for analysis for each background and downgradient well, the dates the samples were collected, and whether the sample was required by the detection monitoring or assessment monitoring programs is included in **Table 1**. The results of the analytical laboratory analyses are provided in the laboratory reports in **Appendix A**.

2.4 §257.90(E)(4) MONITORING TRANSITION NARRATIVE

A narrative discussion of any transition between monitoring programs (e.g., the date and circumstances for transitioning from detection monitoring to assessment monitoring in addition to identifying the constituent(s) detected at a statistically significant increase over background levels);

An Assessment of Corrective Measures (ACM) was initiated for the BGS CCR Units in April 2019, and completed in September 2019. The selection of remedy is in progress. The ACM was initiated in response to the detection of lithium and molybdenum at a statistically significant level exceeding the Groundwater Protection Standards (GPS). Assessment monitoring continued during the ACM and will continue during the selection of remedy.

2.5 §257.90(E)(5) OTHER REQUIREMENTS

Other information required to be included in the annual report as specified in §§257.90 through 257.98.

Additional potentially applicable requirements for the annual report, and the location of the requirement within the Rule, are provided in the following sections. For each cited section of the

Rule, the portion referencing the annual report requirement is provided below in italics, followed by applicable information relative to the 2019 Annual Groundwater Monitoring and Corrective Action Report.

2.5.1 §257.90(e) General Requirements

For the preceding calendar year, the annual report must document the status of the groundwater monitoring and corrective action program for the CCR unit, summarize key actions completed, describe any problems encountered, discuss actions to resolve the problems, and project key activities for the upcoming year.

Status of Groundwater Monitoring and Corrective Action Program. The groundwater monitoring and corrective action program is currently in the selection of remedy process, with assessment monitoring continuing.

Summary of Key Actions Completed:

- Statistical evaluation for the initial Assessment Monitoring samples collected in May, August, and October 2018, completed January 14, 2019.
- Statistical evaluation for the April 2019 monitoring event, completed July 15, 2019.
- Initiation of the ACM on April 15, 2019.
- Two semiannual assessment monitoring events (April and October 2019).
- Installation of two additional compliance groundwater monitoring wells (May 2019) to characterize site conditions in accordance with §257.95(g)(1).
- A sampling event for the new monitoring wells (June 2019).
- Preparation of the ACM report, completed September 12, 2019.

Description of Any Problems Encountered:

- No problems were encountered during the groundwater sampling events in 2019.

Discussion of Actions to Resolve the Problems:

- Not applicable.

Projection of Key Activities for the Upcoming Year (2020):

- Statistical evaluation and determination of any statistically significant levels exceeding the GPS for the October 2019 monitoring event (January 2020).
- Statistical evaluation and determination of any statistically significant levels exceeding the GPS for the April 2020 monitoring event (July 2020).
- Continued work on the selection of remedy in accordance with §257.97.

- Installation of up to four additional monitoring wells to characterize site conditions for the selection of remedy (winter 2020).

- Semiannual progress reports for the Selection of Remedy process (March and September 2020).

- Two semiannual assessment monitoring events (April and October 2020).

2.5.2 §257.94(d) Alternative Detection Monitoring Frequency

The owner or operator must include the demonstration providing the basis for the alternative monitoring frequency and the certification by a qualified professional engineer in the annual groundwater monitoring and corrective action report required by § 257.90(e).

Not applicable. BGS is no longer in the detection monitoring program.

2.5.3 §257.94(e)(2) Alternative Source Demonstration for Detection Monitoring

The owner or operator must also include the demonstration in the annual groundwater monitoring and corrective action report required by §257.90(e), in addition to the certification by a qualified professional engineer.

Not applicable. BGS is no longer in the detection monitoring program.

2.5.4 §257.95(c) Alternative Assessment Monitoring Frequency

The owner or operator must include the demonstration providing the basis for the alternative monitoring frequency and the certification by a qualified professional engineer in the annual groundwater monitoring and corrective action report required by §257.90(e).

Not applicable. Assessment monitoring has been initiated at the site but no alternative assessment monitoring frequency has been proposed at this time.

2.5.5 §257.95(d)(3) Assessment Monitoring Results and Standards

Include the recorded concentrations required by paragraph (d)(1) of this section, identify the background concentrations established under § 257.94(b), and identify the groundwater protection standards established under paragraph (d)(2) of this section in the annual groundwater monitoring and corrective action report required by §257.90(e).

The recorded concentrations for the assessment monitoring events are in the laboratory reports in **Appendix A**. The background concentrations established under 257.94(b) were provided in Appendix A of the 2017 Annual Groundwater Monitoring and Corrective Action Report. The groundwater protection standards established for the BGS CCR units are provided in **Table 2**.

2.5.6 §257.95(g)(3)(ii) Alternative Source Demonstration for Assessment Monitoring

The owner or operator must also include the demonstration in the annual groundwater monitoring and corrective action report required by §257.90(e), in addition to the certification by a qualified professional engineer.

An Alternative Source Demonstration (ASD) was completed in April 2019 and is included in **Appendix B.**

2.5.7 §257.96(a) Extension of Time for Corrective Measures Assessment

The assessment of corrective measures must be completed within 90 days, unless the owner or operator demonstrates the need for additional time to complete the assessment of corrective measure due to site-specific conditions or circumstances. The owner or operator must obtain a certification from a qualified professional engineer attesting that the demonstration is accurate. The 90-day deadline to complete the assessment of corrective measures may be extended for longer than 60 days. The owner or operator must also include the demonstration in the annual groundwater monitoring and corrective action report required by §257.90(e), in addition to the certification by a qualified professional engineer.

The ACM was initiated at the site on July 15, 2019. The July 10, 2019 certification demonstrating the need for a 90-day deadline extension is included in **Appendix C.** The ACM was completed on September 12, 2019.

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Tables

Table 1. CCR Rule Groundwater Samples Summary
Burlington Generating Station / SCS Engineers Project #25219066.00

Sample Dates	Downgradient Wells											Background Wells	
	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306	MW-307	MW-308	MW-309	MW-312	MW-313	MW-310	MW-311
4/3-4/2019	A	A	A	A	A	A	A	A	A	NI	NI	A	A
6/6/2019	--	--	--	--	--	--	--	--	--	A	A	--	--
10/10-11/2019	A	A	A	A	A	A	A	A	A	A	A	A	A
Total Samples	2	2	2	2	2	2	2	2	2	2	2	2	2

Abbreviations:
A = Required by Assessment Monitoring Program
NI = Not Installed

Created by: TK Date: 12/29/2017
Last revision by: LWJ Date: 11/25/2019
Checked by: NDK Date: 1/6/2020

I:\25219066.00\Deliverables\2019 Annual GW Report\Tables\[Table 1 GW_Samples_Summary_Table_BGS.xlsx]GW Summary

Table 2. Groundwater Protection Standards - CCR Program - Assessment Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25219066.00

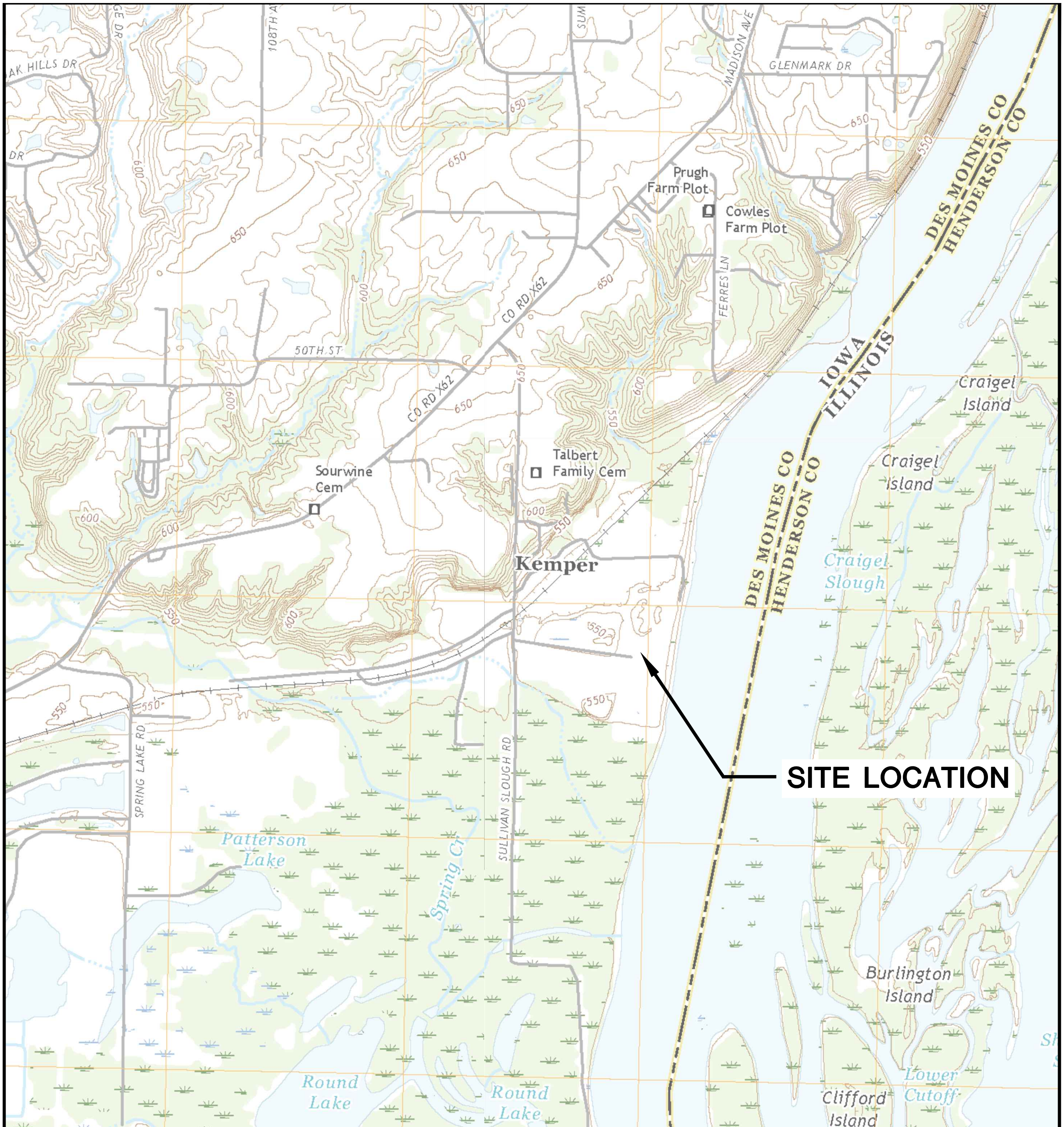
Parameter Name	GPS	Source
Antimony, ug/L	6	MCL
Arsenic, ug/L	115	Background (UPL)
Barium, ug/L	2000	MCL
Beryllium, ug/L	4	MCL
Cadmium, ug/L	5	MCL
Chromium, ug/L	100	MCL
Cobalt, ug/L	6	40 CFR 257.95(h)(2)
Fluoride, mg/L	4	MCL
Lead, ug/L	15	40 CFR 257.95(h)(2)
Lithium, ug/L	40	40 CFR 257.95(h)(2)
Mercury, ug/L	2	MCL
Molybdenum, ug/L	100	40 CFR 257.95(h)(2)
Selenium, ug/L	50	MCL
Thallium, ug/L	2	MCL
Radium 226/228 Combined, pCl/L	5	MCL

Abbreviations:
GPS = Groundwater Protection Standard
MCL = Maximum Contaminant Level established under 40 CFR 141.62 and 141.66
UPL = Upper Prediction Limit.

Created by: NDK, 1/9/2019
Checked by: MDB, 1/9/2019

I:\25219066.00\Deliverables\2019 Annual GW Report\Tables\[Table 2. GPS_BGS-1.xlsx]Table

Figures



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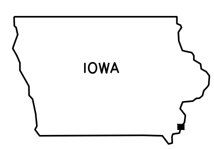
LOMAX QUADRANGLE
ILLINOIS / IOWA-DES MOINES CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
2018
SCALE: 1" = 2,000'



CLIENT	ALLIANT ENERGY 4902 N. BILTMORE LANE, #1000 MADISON, WI 53718	SITE	ALLIANT ENERGY BURLINGTON GENERATING STATION BURLINGTON, IOWA
			SITE LOCATION MAP

PROJECT NO.	25219066.00	DRAWN BY:	BSS	ENGINEER	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	FIGURE
DRAWN:	11/14/2019	CHECKED BY:	MDB			1
REVISED:	01/14/2020	APPROVED BY:	TK 01/30/2020			

I:\2521□066.00\Drawings\□□□ 201□ Ann□a□□eport\Site Location Map.dwg, 1/30/2020 3:35:22 □M

LEGEND

- EXISTING CCR RULE MONITORING WELL
- CCR UNITS

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW-301, MW-302, AND MW-309 THROUGH MW-311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
4. 2018 AERIAL PHOTOGRAPH SOURCES: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA FSA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY.

N

300 0 300

SCALE: 1" = 300'

PROJECT NO.	25219066.00	DRAWN BY:	BSS
DRAWN:	11/14/2019	CHECKED BY:	MDB
REVISED:	01/20/2020	APPROVED BY:	TK 01/30/2020

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY
4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

SITE PLAN AND MONITORING WELL LOCATIONS

FIGURE 2

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Appendix A

Analytical Laboratory Reports

A1 Assessment Monitoring, April 2019

eurofins

Environment Testing
TestAmerica

ANALYTICAL REPORT

Eurofins TestAmerica, Cedar Falls
3019 Venture Way
Cedar Falls, IA 50613
Tel: (319)277-2401

Laboratory Job ID: 310-152684-1
Laboratory Sample Delivery Group: 25216066
Client Project/Site: Burlington - 25216066
Revision: 1

For:
SCS Engineers
2830 Dairy Drive
Madison, Wisconsin 53718

Attn: Meghan Blodgett

Authorized for release by:
7/11/2019 9:16:11 AM

Sandie Fredrick, Project Manager II
(920)261-1660
sandie.fredrick@testamericainc.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at: www.testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Table of Contents

Job ID: 310-152684-1

Laboratory: Eurofins TestAmerica, Cedar Falls

Narrative

Job Narrative
310-152684-1

Comments
REVISION: Client requested split reports

Receipt
The samples were received on 4/4/2019 6:00 PM; the samples arrived in good condition, properly preserved and, where required, on ice. The temperatures of the 3 coolers at receipt time were 1.7º C, 3.8º C and 4.2º C.

HPLC/IC
Method(s) 9056A: The following samples were diluted due to the nature of the sample matrix: MW 302 (310-152684-2), MW 303 (310-152684-3), MW 304 (310-152684-4), MW 306 (310-152684-6), MW 308 (310-152684-8) and MW 311 (310-152684-11). Elevated reporting limits (RLs) are provided.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

Metals
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

General Chemistry
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Sample Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Lab Sample ID	Client Sample ID	Matrix	Collected	Received	Asset ID
310-152684-1	MW 301	Ground Water	04/03/19 14:20	04/04/19 18:00	
310-152684-2	MW 302	Ground Water	04/03/19 15:22	04/04/19 18:00	
310-152684-3	MW 303	Ground Water	04/03/19 16:02	04/04/19 18:00	
310-152684-4	MW 304	Ground Water	04/03/19 17:00	04/04/19 18:00	
310-152684-5	MW 305	Ground Water	04/03/19 13:16	04/04/19 18:00	
310-152684-6	MW 306	Ground Water	04/03/19 11:22	04/04/19 18:00	
310-152684-7	MW 307	Ground Water	04/03/19 12:05	04/04/19 18:00	
310-152684-8	MW 308	Ground Water	04/03/19 10:33	04/04/19 18:00	
310-152684-9	MW 309	Ground Water	04/04/19 10:33	04/04/19 18:00	
310-152684-10	MW 310	Ground Water	04/04/19 08:50	04/04/19 18:00	
310-152684-11	MW 311	Ground Water	04/04/19 09:34	04/04/19 18:00	
310-152684-12	Field Blank	Ground Water	04/03/19 13:25	04/04/19 18:00	

Detection Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 301 — Lab Sample ID: 310-152684-1

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	21		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.77		0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	190		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	42		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	380		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	12000		2000	1100	ug/L	10		6020A	Total/NA
Calcium	150		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.44	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lithium	13		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	77		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	890		30	24	mg/L	1		SM 2540C	Total/NA
pH	7.0	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Field Conductivity	1213				umhos/cm	1		Field Sampling	Total/NA
Field Dissolved Oxygen	0.59				mg/L	1		Field Sampling	Total/NA
Field pH	7.53				SU	1		Field Sampling	Total/NA
Field Temperature	12.35				Degrees C	1		Field Sampling	Total/NA
Field Turbidity	21.10				NTU	1		Field Sampling	Total/NA
Groundwater Elevation (ft MSL)	528.15				ft	1		Field Sampling	Total/NA
Oxidation Reduction Potential	-144.7				millivolts	1		Field Sampling	Total/NA

Client Sample ID: MW 302 — Lab Sample ID: 310-152684-2

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	13		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.37	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	510		20	7.0	mg/L	20		9056A	Total/NA
Arsenic	53		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	320		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	12000		2000	1100	ug/L	10		6020A	Total/NA
Calcium	220		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.19	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lead	0.58		0.50	0.27	ug/L	1		6020A	Total/NA
Lithium	56		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	100		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	1000		30	24	mg/L	1		SM 2540C	Total/NA
pH	8.1	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Field Conductivity	1164				umhos/cm	1		Field Sampling	Total/NA
Field Dissolved Oxygen	0.58				mg/L	1		Field Sampling	Total/NA
Field pH	8.70				SU	1		Field Sampling	Total/NA
Field Temperature	11.41				Degrees C	1		Field Sampling	Total/NA
Field Turbidity	18.80				NTU	1		Field Sampling	Total/NA
Groundwater Elevation (ft MSL)	528.21				ft	1		Field Sampling	Total/NA
Oxidation Reduction Potential	-215.8				millivolts	1		Field Sampling	Total/NA

Client Sample ID: MW 303 — Lab Sample ID: 310-152684-3

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	15		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.43	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	120		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	6.4		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	440		2.0	0.84	ug/L	1		6020A	Total/NA

This Detection Summary does not include radiochemical test results.

Detection Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 303 (Continued)

Lab Sample ID: 310-152684-3

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Boron	22000		2000	1100	ug/L	10		6020A	Total/NA
Calcium	86		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.36	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lead	0.49	J	0.50	0.27	ug/L	1		6020A	Total/NA
Lithium	52		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	110		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	540		30	24	mg/L	1		SM 2540C	Total/NA
pH	7.4	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Field Conductivity	711				umhos/cm	1		Field Sampling	Total/NA
Field Dissolved Oxygen	0.67				mg/L	1		Field Sampling	Total/NA
Field pH	7.79				SU	1		Field Sampling	Total/NA
Field Temperature	12.63				Degrees C	1		Field Sampling	Total/NA
Field Turbidity	18.20				NTU	1		Field Sampling	Total/NA
Groundwater Elevation (ft MSL)	528.22				ft	1		Field Sampling	Total/NA
Oxidation Reduction Potential	-122.8				millivolts	1		Field Sampling	Total/NA

Client Sample ID: MW 304

Lab Sample ID: 310-152684-4

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	39		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.35	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	140		5.0	1.8	mg/L	5		9056A	Total/NA
Antimony	0.66	J	1.0	0.53	ug/L	1		6020A	Total/NA
Arsenic	59		20	7.5	ug/L	10		6020A	Total/NA
Barium	90		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	6300		2000	1100	ug/L	10		6020A	Total/NA
Calcium	72		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.11	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lithium	52		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	58		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	460		30	24	mg/L	1		SM 2540C	Total/NA
pH	8.0	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Field Conductivity	658				umhos/cm	1		Field Sampling	Total/NA
Field Dissolved Oxygen	0.39				mg/L	1		Field Sampling	Total/NA
Field pH	8.56				SU	1		Field Sampling	Total/NA
Field Temperature	12.96				Degrees C	1		Field Sampling	Total/NA
Field Turbidity	6.22				NTU	1		Field Sampling	Total/NA
Groundwater Elevation (ft MSL)	528.27				ft	1		Field Sampling	Total/NA
Oxidation Reduction Potential	-216.7				millivolts	1		Field Sampling	Total/NA

Client Sample ID: MW 305

Lab Sample ID: 310-152684-5

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	33		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.75		0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	10		5.0	1.8	mg/L	5		9056A	Total/NA
Barium	160		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	2000		200	110	ug/L	1		6020A	Total/NA
Calcium	83		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.16	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lithium	29		10	2.7	ug/L	1		6020A	Total/NA
Total Dissolved Solids	470		30	24	mg/L	1		SM 2540C	Total/NA

This Detection Summary does not include radiochemical test results.

Eurofins TestAmerica, Cedar Falls

Detection Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Client Sample ID: MW 305 (Continued)

Lab Sample ID: 310-152684-5

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
pH	7.4	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Field Conductivity	733				umhos/cm	1		Field Sampling	Total/NA
Field Dissolved Oxygen	0.59				mg/L	1		Field Sampling	Total/NA
Field pH	7.80				SU	1		Field Sampling	Total/NA
Field Temperature	14.47				Degrees C	1		Field Sampling	Total/NA
Field Turbidity	3.88				NTU	1		Field Sampling	Total/NA
Groundwater Elevation (ft MSL)	528.36				ft	1		Field Sampling	Total/NA
Oxidation Reduction Potential	-133.5				millivolts	1		Field Sampling	Total/NA

Client Sample ID: MW 306

Lab Sample ID: 310-152684-6

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	21		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.36	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	110		5.0	1.8	mg/L	5		9056A	Total/NA
Antimony	1.1		1.0	0.53	ug/L	1		6020A	Total/NA
Arsenic	50		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	14		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	2900		200	110	ug/L	1		6020A	Total/NA
Calcium	37		0.50	0.10	mg/L	1		6020A	Total/NA
Lithium	45		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	78		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	320		30	24	mg/L	1		SM 2540C	Total/NA
pH	6.0	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Field Conductivity	4711				umhos/cm	1		Field Sampling	Total/NA
Field Dissolved Oxygen	0.69				mg/L	1		Field Sampling	Total/NA
Field pH	6.69				SU	1		Field Sampling	Total/NA
Field Temperature	13.44				Degrees C	1		Field Sampling	Total/NA
Field Turbidity	0.81				NTU	1		Field Sampling	Total/NA
Groundwater Elevation (ft MSL)	528.40				ft	1		Field Sampling	Total/NA
Oxidation Reduction Potential	-92.8				millivolts	1		Field Sampling	Total/NA

Client Sample ID: MW 307

Lab Sample ID: 310-152684-7

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	21		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.51		0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	120		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	43		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	29		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	3400		200	110	ug/L	1		6020A	Total/NA
Calcium	29		0.50	0.10	mg/L	1		6020A	Total/NA
Lead	0.37	J	0.50	0.27	ug/L	1		6020A	Total/NA
Lithium	50		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	100		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	420		30	24	mg/L	1		SM 2540C	Total/NA
pH	10.0	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Field Conductivity	500				umhos/cm	1		Field Sampling	Total/NA
Field Dissolved Oxygen	0.68				mg/L	1		Field Sampling	Total/NA
Field pH	10.39				SU	1		Field Sampling	Total/NA
Field Temperature	13.56				Degrees C	1		Field Sampling	Total/NA
Field Turbidity	3.10				NTU	1		Field Sampling	Total/NA

This Detection Summary does not include radiochemical test results.

Client Sample ID: MW 307 (Continued) — Lab Sample ID: 310-152684-7

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Groundwater Elevation (ft MSL)	528.63				ft	1		Field Sampling	Total/NA
Oxidation Reduction Potential	-167.8				millivolts	1		Field Sampling	Total/NA

Client Sample ID: MW 308 — Lab Sample ID: 310-152684-8

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	38		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.37	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	170		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	78		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	70		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	4300		400	220	ug/L	2		6020A	Total/NA
Calcium	32		0.50	0.10	mg/L	1		6020A	Total/NA
Lithium	50		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	110		4.0	2.2	ug/L	2		6020A	Total/NA
Total Dissolved Solids	490		30	24	mg/L	1		SM 2540C	Total/NA
pH	9.6	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Field Conductivity	681				umhos/cm	1		Field Sampling	Total/NA
Field Dissolved Oxygen	1.16				mg/L	1		Field Sampling	Total/NA
Field pH	9.97				SU	1		Field Sampling	Total/NA
Field Temperature	14.04				Degrees C	1		Field Sampling	Total/NA
Field Turbidity	1.66				NTU	1		Field Sampling	Total/NA
Groundwater Elevation (ft MSL)	528.39				ft	1		Field Sampling	Total/NA
Oxidation Reduction Potential	-142.3				millivolts	1		Field Sampling	Total/NA

Client Sample ID: MW 309 — Lab Sample ID: 310-152684-9

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	100		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.71		0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	78		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	30		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	130		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	4200		400	220	ug/L	2		6020A	Total/NA
Calcium	73		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	1.3		0.50	0.091	ug/L	1		6020A	Total/NA
Lithium	3.3	J	10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	47		4.0	2.2	ug/L	2		6020A	Total/NA
Total Dissolved Solids	650		30	24	mg/L	1		SM 2540C	Total/NA
pH	7.1	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Field Conductivity	997				umhos/cm	1		Field Sampling	Total/NA
Field Dissolved Oxygen	0.51				mg/L	1		Field Sampling	Total/NA
Field pH	7.45				SU	1		Field Sampling	Total/NA
Field Temperature	12.60				Degrees C	1		Field Sampling	Total/NA
Field Turbidity	20.1				NTU	1		Field Sampling	Total/NA
Groundwater Elevation (ft MSL)	528.40				ft	1		Field Sampling	Total/NA
Oxidation Reduction Potential	-99.4				millivolts	1		Field Sampling	Total/NA

Client Sample ID: MW 310 — Lab Sample ID: 310-152684-10

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	88		5.0	1.5	mg/L	5		9056A	Total/NA

This Detection Summary does not include radiochemical test results.

Detection Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 310 (Continued)

Lab Sample ID: 310-152684-10

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Fluoride	0.55		0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	21		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	65		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	560		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	560		200	110	ug/L	1		6020A	Total/NA
Calcium	120		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	1.9		0.50	0.091	ug/L	1		6020A	Total/NA
Molybdenum	5.2		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	600		30	24	mg/L	1		SM 2540C	Total/NA
pH	7.0	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Field Conductivity	1034				umhos/cm	1		Field Sampling	Total/NA
Field Dissolved Oxygen	1.12				mg/L	1		Field Sampling	Total/NA
Field pH	7.84				SU	1		Field Sampling	Total/NA
Field Temperature	10.8				Degrees C	1		Field Sampling	Total/NA
Field Turbidity	16.70				NTU	1		Field Sampling	Total/NA
Groundwater Elevation (ft MSL)	528.62				ft	1		Field Sampling	Total/NA
Oxidation Reduction Potential	-175.8				millivolts	1		Field Sampling	Total/NA

Client Sample ID: MW 311

Lab Sample ID: 310-152684-11

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	110		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.41	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	230		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	19		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	280		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	1800		200	110	ug/L	1		6020A	Total/NA
Calcium	200		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.45	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lead	0.37	J	0.50	0.27	ug/L	1		6020A	Total/NA
Molybdenum	8.5		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	980		30	24	mg/L	1		SM 2540C	Total/NA
pH	7.0	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Field Conductivity	1422				umhos/cm	1		Field Sampling	Total/NA
Field Dissolved Oxygen	0.78				mg/L	1		Field Sampling	Total/NA
Field pH	7.64				SU	1		Field Sampling	Total/NA
Field Temperature	11.41				Degrees C	1		Field Sampling	Total/NA
Field Turbidity	10.80				NTU	1		Field Sampling	Total/NA
Groundwater Elevation (ft MSL)	528.20				ft	1		Field Sampling	Total/NA
Oxidation Reduction Potential	145.8				millivolts	1		Field Sampling	Total/NA

Client Sample ID: Field Blank

Lab Sample ID: 310-152684-12

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Fluoride	0.062	J	0.10	0.045	mg/L	1		9056A	Total/NA
Boron	140	J	200	110	ug/L	1		6020A	Total/NA
Total Dissolved Solids	48		30	24	mg/L	1		SM 2540C	Total/NA
pH	7.0	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA

This Detection Summary does not include radiochemical test results.

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 301

Lab Sample ID: 310-152684-1

Date Collected: 04/03/19 14:20
Date Received: 04/04/19 18:00

Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**21**		5.0	1.5	mg/L			04/08/19 20:30	5
Fluoride	**0.77**		0.50	0.23	mg/L			04/08/19 20:30	5
Sulfate	**190**		5.0	1.8	mg/L			04/08/19 20:30	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 18:41	1
Arsenic	**42**		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 18:41	1
Barium	**380**		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 18:41	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 18:41	1
Boron	**12000**		2000	1100	ug/L		04/08/19 08:00	04/18/19 20:33	10
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 18:41	1
Calcium	**150**		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 18:41	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 18:41	1
Cobalt	**0.44**	**J**	0.50	0.091	ug/L		04/08/19 08:00	04/18/19 18:41	1
Lead	<0.27		0.50	0.27	ug/L		04/08/19 08:00	04/18/19 18:41	1
Lithium	**13**		10	2.7	ug/L		04/08/19 08:00	04/18/19 18:41	1
Molybdenum	**77**		2.0	1.1	ug/L		04/08/19 08:00	04/19/19 16:11	1
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 18:41	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 18:41	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:04	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**890**		30	24	mg/L			04/08/19 11:48	1
pH	**7.0**	**HF**	0.1	0.1	SU			04/05/19 00:33	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Field Conductivity	**1213**				umhos/cm			04/03/19 14:20	1
Field Dissolved Oxygen	**0.59**				mg/L			04/03/19 14:20	1
Field pH	**7.53**				SU			04/03/19 14:20	1
Field Temperature	**12.35**				Degrees C			04/03/19 14:20	1
Field Turbidity	**21.10**				NTU			04/03/19 14:20	1
Groundwater Elevation (ft MSL)	**528.15**				ft			04/03/19 14:20	1
Oxidation Reduction Potential	**-144.7**				millivolts			04/03/19 14:20	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 302

Date Collected: 04/03/19 15:22
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-2

Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**13**		5.0	1.5	mg/L			04/08/19 20:43	5
Fluoride	**0.37**	**J**	0.50	0.23	mg/L			04/08/19 20:43	5
Sulfate	**510**		20	7.0	mg/L			04/09/19 08:59	20

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 18:51	1
Arsenic	**53**		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 18:51	1
Barium	**320**		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 18:51	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 18:51	1
Boron	**12000**		2000	1100	ug/L		04/08/19 08:00	04/18/19 20:43	10
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 18:51	1
Calcium	**220**		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 18:51	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 18:51	1
Cobalt	**0.19**	**J**	0.50	0.091	ug/L		04/08/19 08:00	04/18/19 18:51	1
Lead	**0.58**		0.50	0.27	ug/L		04/08/19 08:00	04/18/19 18:51	1
Lithium	**56**		10	2.7	ug/L		04/08/19 08:00	04/18/19 18:51	1
Molybdenum	**100**		2.0	1.1	ug/L		04/08/19 08:00	04/19/19 16:21	1
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 18:51	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 18:51	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:06	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**1000**		30	24	mg/L			04/08/19 11:48	1
pH	**8.1**	**HF**	0.1	0.1	SU			04/05/19 00:36	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Field Conductivity	**1164**				umhos/cm			04/03/19 15:22	1
Field Dissolved Oxygen	**0.58**				mg/L			04/03/19 15:22	1
Field pH	**8.70**				SU			04/03/19 15:22	1
Field Temperature	**11.41**				Degrees C			04/03/19 15:22	1
Field Turbidity	**18.80**				NTU			04/03/19 15:22	1
Groundwater Elevation (ft MSL)	**528.21**				ft			04/03/19 15:22	1
Oxidation Reduction Potential	**-215.8**				millivolts			04/03/19 15:22	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 303

Date Collected: 04/03/19 16:02
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-3

Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	15		5.0	1.5	mg/L			04/08/19 20:57	5
Fluoride	0.43	J	0.50	0.23	mg/L			04/08/19 20:57	5
Sulfate	120		5.0	1.8	mg/L			04/08/19 20:57	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 18:54	1
Arsenic	6.4		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 18:54	1
Barium	440		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 18:54	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 18:54	1
Boron	22000		2000	1100	ug/L		04/08/19 08:00	04/18/19 20:47	10
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 18:54	1
Calcium	86		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 18:54	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 18:54	1
Cobalt	0.36	J	0.50	0.091	ug/L		04/08/19 08:00	04/18/19 18:54	1
Lead	0.49	J	0.50	0.27	ug/L		04/08/19 08:00	04/18/19 18:54	1
Lithium	52		10	2.7	ug/L		04/08/19 08:00	04/18/19 18:54	1
Molybdenum	110		2.0	1.1	ug/L		04/08/19 08:00	04/19/19 16:24	1
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 18:54	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 18:54	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:17	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	540		30	24	mg/L			04/08/19 11:48	1
pH	7.4	HF	0.1	0.1	SU			04/05/19 00:38	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Field Conductivity	711				umhos/cm			04/03/19 16:02	1
Field Dissolved Oxygen	0.67				mg/L			04/03/19 16:02	1
Field pH	7.79				SU			04/03/19 16:02	1
Field Temperature	12.63				Degrees C			04/03/19 16:02	1
Field Turbidity	18.20				NTU			04/03/19 16:02	1
Groundwater Elevation (ft MSL)	528.22				ft			04/03/19 16:02	1
Oxidation Reduction Potential	-122.8				millivolts			04/03/19 16:02	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 304

Date Collected: 04/03/19 17:00
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-4

Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	39		5.0	1.5	mg/L			04/08/19 21:24	5
Fluoride	0.35	J	0.50	0.23	mg/L			04/08/19 21:24	5
Sulfate	140		5.0	1.8	mg/L			04/08/19 21:24	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	0.66	J	1.0	0.53	ug/L		04/08/19 08:00	04/18/19 18:58	1
Arsenic	59		20	7.5	ug/L		04/08/19 08:00	04/18/19 20:50	10
Barium	90		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 18:58	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 18:58	1
Boron	6300		2000	1100	ug/L		04/08/19 08:00	04/18/19 20:50	10
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 18:58	1
Calcium	72		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 18:58	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 18:58	1
Cobalt	0.11	J	0.50	0.091	ug/L		04/08/19 08:00	04/18/19 18:58	1
Lead	<0.27		0.50	0.27	ug/L		04/08/19 08:00	04/18/19 18:58	1
Lithium	52		10	2.7	ug/L		04/08/19 08:00	04/18/19 18:58	1
Molybdenum	58		2.0	1.1	ug/L		04/08/19 08:00	04/19/19 16:27	1
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 18:58	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 18:58	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:19	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	460		30	24	mg/L			04/08/19 11:48	1
pH	8.0	HF	0.1	0.1	SU			04/05/19 00:40	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Field Conductivity	658				umhos/cm			04/03/19 17:00	1
Field Dissolved Oxygen	0.39				mg/L			04/03/19 17:00	1
Field pH	8.56				SU			04/03/19 17:00	1
Field Temperature	12.96				Degrees C			04/03/19 17:00	1
Field Turbidity	6.22				NTU			04/03/19 17:00	1
Groundwater Elevation (ft MSL)	528.27				ft			04/03/19 17:00	1
Oxidation Reduction Potential	-216.7				millivolts			04/03/19 17:00	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 305

Date Collected: 04/03/19 13:16
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-5

Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**33**		5.0	1.5	mg/L			04/08/19 21:51	5
Fluoride	**0.75**		0.50	0.23	mg/L			04/08/19 21:51	5
Sulfate	**10**		5.0	1.8	mg/L			04/08/19 21:51	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 19:11	1
Arsenic	<0.75		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 19:11	1
Barium	**160**		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 19:11	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:11	1
Boron	**2000**		200	110	ug/L		04/08/19 08:00	04/19/19 16:31	1
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 19:11	1
Calcium	**83**		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 19:11	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 19:11	1
Cobalt	**0.16**	**J**	0.50	0.091	ug/L		04/08/19 08:00	04/18/19 19:11	1
Lead	<0.27		0.50	0.27	ug/L		04/08/19 08:00	04/18/19 19:11	1
Lithium	**29**		10	2.7	ug/L		04/08/19 08:00	04/18/19 19:11	1
Molybdenum	<1.1		2.0	1.1	ug/L		04/08/19 08:00	04/19/19 16:31	1
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 19:11	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:11	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:21	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**470**		30	24	mg/L			04/08/19 11:48	1
pH	**7.4**	**HF**	0.1	0.1	SU			04/05/19 00:46	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Field Conductivity	**733**				umhos/cm			04/03/19 13:16	1
Field Dissolved Oxygen	**0.59**				mg/L			04/03/19 13:16	1
Field pH	**7.80**				SU			04/03/19 13:16	1
Field Temperature	**14.47**				Degrees C			04/03/19 13:16	1
Field Turbidity	**3.88**				NTU			04/03/19 13:16	1
Groundwater Elevation (ft MSL)	**528.36**				ft			04/03/19 13:16	1
Oxidation Reduction Potential	**-133.5**				millivolts			04/03/19 13:16	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 306

Lab Sample ID: 310-152684-6

Date Collected: 04/03/19 11:22
Date Received: 04/04/19 18:00

Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**21**		5.0	1.5	mg/L			04/08/19 22:18	5
Fluoride	**0.36**	**J**	0.50	0.23	mg/L			04/08/19 22:18	5
Sulfate	**110**		5.0	1.8	mg/L			04/08/19 22:18	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	**1.1**		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 19:14	1
Arsenic	**50**		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 19:14	1
Barium	**14**		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 19:14	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:14	1
Boron	**2900**		200	110	ug/L		04/08/19 08:00	04/19/19 16:44	1
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 19:14	1
Calcium	**37**		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 19:14	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 19:14	1
Cobalt	<0.091		0.50	0.091	ug/L		04/08/19 08:00	04/18/19 19:14	1
Lead	<0.27		0.50	0.27	ug/L		04/08/19 08:00	04/18/19 19:14	1
Lithium	**45**		10	2.7	ug/L		04/08/19 08:00	04/18/19 19:14	1
Molybdenum	**78**		2.0	1.1	ug/L		04/08/19 08:00	04/19/19 16:44	1
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 19:14	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:14	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:23	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**320**		30	24	mg/L			04/09/19 10:18	1
pH	**6.0**	**HF**	0.1	0.1	SU			04/05/19 00:50	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Field Conductivity	**4711**				umhos/cm			04/03/19 11:22	1
Field Dissolved Oxygen	**0.69**				mg/L			04/03/19 11:22	1
Field pH	**6.69**				SU			04/03/19 11:22	1
Field Temperature	**13.44**				Degrees C			04/03/19 11:22	1
Field Turbidity	**0.81**				NTU			04/03/19 11:22	1
Groundwater Elevation (ft MSL)	**528.40**				ft			04/03/19 11:22	1
Oxidation Reduction Potential	**-92.8**				millivolts			04/03/19 11:22	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Client Sample ID: MW 307

Lab Sample ID: 310-152684-7

Date Collected: 04/03/19 12:05
Date Received: 04/04/19 18:00

Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**21**		5.0	1.5	mg/L			04/08/19 23:13	5
Fluoride	**0.51**		0.50	0.23	mg/L			04/08/19 23:13	5
Sulfate	**120**		5.0	1.8	mg/L			04/08/19 23:13	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 19:17	1
Arsenic	**43**		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 19:17	1
Barium	**29**		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 19:17	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:17	1
Boron	**3400**		200	110	ug/L		04/08/19 08:00	04/19/19 16:47	1
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 19:17	1
Calcium	**29**		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 19:17	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 19:17	1
Cobalt	<0.091		0.50	0.091	ug/L		04/08/19 08:00	04/18/19 19:17	1
Lead	**0.37**	**J**	0.50	0.27	ug/L		04/08/19 08:00	04/18/19 19:17	1
Lithium	**50**		10	2.7	ug/L		04/08/19 08:00	04/18/19 19:17	1
Molybdenum	**100**		2.0	1.1	ug/L		04/08/19 08:00	04/19/19 16:47	1
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 19:17	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:17	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:25	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**420**		30	24	mg/L			04/09/19 10:18	1
pH	**10.0**	**HF**	0.1	0.1	SU			04/05/19 00:51	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Field Conductivity	**500**				umhos/cm			04/03/19 12:05	1
Field Dissolved Oxygen	**0.68**				mg/L			04/03/19 12:05	1
Field pH	**10.39**				SU			04/03/19 12:05	1
Field Temperature	**13.56**				Degrees C			04/03/19 12:05	1
Field Turbidity	**3.10**				NTU			04/03/19 12:05	1
Groundwater Elevation (ft MSL)	**528.63**				ft			04/03/19 12:05	1
Oxidation Reduction Potential	**-167.8**				millivolts			04/03/19 12:05	1

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 308

Date Collected: 04/03/19 10:33
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-8
Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	38		5.0	1.5	mg/L			04/08/19 23:26	5
Fluoride	0.37	J	0.50	0.23	mg/L			04/08/19 23:26	5
Sulfate	170		5.0	1.8	mg/L			04/08/19 23:26	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 19:47	1
Arsenic	78		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 19:47	1
Barium	70		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 19:47	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:47	1
Boron	4300		400	220	ug/L		04/08/19 08:00	04/19/19 16:51	2
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 19:47	1
Calcium	32		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 19:47	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 19:47	1
Cobalt	<0.091		0.50	0.091	ug/L		04/08/19 08:00	04/18/19 19:47	1
Lead	<0.27		0.50	0.27	ug/L		04/08/19 08:00	04/18/19 19:47	1
Lithium	50		10	2.7	ug/L		04/08/19 08:00	04/18/19 19:47	1
Molybdenum	110		4.0	2.2	ug/L		04/08/19 08:00	04/19/19 16:51	2
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 19:47	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:47	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:27	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	490		30	24	mg/L			04/09/19 10:18	1
pH	9.6	HF	0.1	0.1	SU			04/05/19 00:53	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Field Conductivity	681				umhos/cm			04/03/19 10:33	1
Field Dissolved Oxygen	1.16				mg/L			04/03/19 10:33	1
Field pH	9.97				SU			04/03/19 10:33	1
Field Temperature	14.04				Degrees C			04/03/19 10:33	1
Field Turbidity	1.66				NTU			04/03/19 10:33	1
Groundwater Elevation (ft MSL)	528.39				ft			04/03/19 10:33	1
Oxidation Reduction Potential	-142.3				millivolts			04/03/19 10:33	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 309

Date Collected: 04/04/19 10:33
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-9
Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**100**		5.0	1.5	mg/L			04/08/19 23:40	5
Fluoride	**0.71**		0.50	0.23	mg/L			04/08/19 23:40	5
Sulfate	**78**		5.0	1.8	mg/L			04/08/19 23:40	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 19:51	1
Arsenic	**30**		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 19:51	1
Barium	**130**		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 19:51	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:51	1
Boron	**4200**		400	220	ug/L		04/08/19 08:00	04/19/19 16:54	2
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 19:51	1
Calcium	**73**		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 19:51	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 19:51	1
Cobalt	**1.3**		0.50	0.091	ug/L		04/08/19 08:00	04/18/19 19:51	1
Lead	<0.27		0.50	0.27	ug/L		04/08/19 08:00	04/18/19 19:51	1
Lithium	**3.3**	**J**	10	2.7	ug/L		04/08/19 08:00	04/18/19 19:51	1
Molybdenum	**47**		4.0	2.2	ug/L		04/08/19 08:00	04/19/19 16:54	2
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 19:51	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:51	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:29	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**650**		30	24	mg/L			04/09/19 10:18	1
pH	**7.1**	**HF**	0.1	0.1	SU			04/05/19 00:55	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Field Conductivity	**997**				umhos/cm			04/04/19 10:33	1
Field Dissolved Oxygen	**0.51**				mg/L			04/04/19 10:33	1
Field pH	**7.45**				SU			04/04/19 10:33	1
Field Temperature	**12.60**				Degrees C			04/04/19 10:33	1
Field Turbidity	**20.1**				NTU			04/04/19 10:33	1
Groundwater Elevation (ft MSL)	**528.40**				ft			04/04/19 10:33	1
Oxidation Reduction Potential	**-99.4**				millivolts			04/04/19 10:33	1

Client Sample ID: MW 310

Date Collected: 04/04/19 08:50
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-10
Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**88**		5.0	1.5	mg/L			04/08/19 23:54	5
Fluoride	**0.55**		0.50	0.23	mg/L			04/08/19 23:54	5
Sulfate	**21**		5.0	1.8	mg/L			04/08/19 23:54	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 19:54	1
Arsenic	**65**		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 19:54	1
Barium	**560**		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 19:54	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:54	1
Boron	**560**		200	110	ug/L		04/08/19 08:00	04/19/19 16:57	1
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 19:54	1
Calcium	**120**		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 19:54	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 19:54	1
Cobalt	**1.9**		0.50	0.091	ug/L		04/08/19 08:00	04/18/19 19:54	1
Lead	<0.27		0.50	0.27	ug/L		04/08/19 08:00	04/18/19 19:54	1
Lithium	<2.7		10	2.7	ug/L		04/08/19 08:00	04/18/19 19:54	1
Molybdenum	**5.2**		2.0	1.1	ug/L		04/08/19 08:00	04/19/19 16:57	1
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 19:54	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:54	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:32	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**600**		30	24	mg/L			04/09/19 10:18	1
pH	**7.0**	**HF**	0.1	0.1	SU			04/05/19 00:57	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Field Conductivity	**1034**				umhos/cm			04/04/19 08:50	1
Field Dissolved Oxygen	**1.12**				mg/L			04/04/19 08:50	1
Field pH	**7.84**				SU			04/04/19 08:50	1
Field Temperature	**10.8**				Degrees C			04/04/19 08:50	1
Field Turbidity	**16.70**				NTU			04/04/19 08:50	1
Groundwater Elevation (ft MSL)	**528.62**				ft			04/04/19 08:50	1
Oxidation Reduction Potential	**-175.8**				millivolts			04/04/19 08:50	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 311

Date Collected: 04/04/19 09:34
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-11
Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**110**		5.0	1.5	mg/L			04/09/19 00:07	5
Fluoride	**0.41**	**J**	0.50	0.23	mg/L			04/09/19 00:07	5
Sulfate	**230**		5.0	1.8	mg/L			04/09/19 00:07	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 19:57	1
Arsenic	**19**		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 19:57	1
Barium	**280**		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 19:57	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:57	1
Boron	**1800**		200	110	ug/L		04/08/19 08:00	04/19/19 17:01	1
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 19:57	1
Calcium	**200**		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 19:57	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 19:57	1
Cobalt	**0.45**	**J**	0.50	0.091	ug/L		04/08/19 08:00	04/18/19 19:57	1
Lead	**0.37**	**J**	0.50	0.27	ug/L		04/08/19 08:00	04/18/19 19:57	1
Lithium	<2.7		10	2.7	ug/L		04/08/19 08:00	04/18/19 19:57	1
Molybdenum	**8.5**		2.0	1.1	ug/L		04/08/19 08:00	04/19/19 17:01	1
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 19:57	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 19:57	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:34	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**980**		30	24	mg/L			04/09/19 10:18	1
pH	**7.0**	**HF**	0.1	0.1	SU			04/05/19 00:59	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Field Conductivity	**1422**				umhos/cm			04/04/19 09:34	1
Field Dissolved Oxygen	**0.78**				mg/L			04/04/19 09:34	1
Field pH	**7.64**				SU			04/04/19 09:34	1
Field Temperature	**11.41**				Degrees C			04/04/19 09:34	1
Field Turbidity	**10.80**				NTU			04/04/19 09:34	1
Groundwater Elevation (ft MSL)	**528.20**				ft			04/04/19 09:34	1
Oxidation Reduction Potential	**145.8**				millivolts			04/04/19 09:34	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: Field Blank

Date Collected: 04/03/19 13:25
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-12
Matrix: Ground Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	<0.29		1.0	0.29	mg/L			04/09/19 00:21	1
Fluoride	**0.062**	**J**	0.10	0.045	mg/L			04/09/19 00:21	1
Sulfate	<0.35		1.0	0.35	mg/L			04/09/19 00:21	1

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 20:04	1
Arsenic	<0.75		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 20:04	1
Barium	<0.84		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 20:04	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 20:04	1
Boron	**140**	**J**	200	110	ug/L		04/08/19 08:00	04/19/19 17:07	1
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 20:04	1
Calcium	<0.10		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 20:04	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 20:04	1
Cobalt	<0.091		0.50	0.091	ug/L		04/08/19 08:00	04/18/19 20:04	1
Lead	<0.27		0.50	0.27	ug/L		04/08/19 08:00	04/18/19 20:04	1
Lithium	<2.7		10	2.7	ug/L		04/08/19 08:00	04/18/19 20:04	1
Molybdenum	<1.1		2.0	1.1	ug/L		04/08/19 08:00	04/19/19 17:07	1
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 20:04	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 20:04	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:36	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**48**		30	24	mg/L			04/09/19 10:18	1
pH	**7.0**	**HF**	0.1	0.1	SU			04/05/19 01:06	1

Qualifiers

HPLC/IC

Qualifier	Qualifier Description
J	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

Metals

Qualifier	Qualifier Description
4	MS, MSD: The analyte present in the original sample is greater than 4 times the matrix spike concentration; therefore, control limits are not applicable.
J	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

General Chemistry

Qualifier	Qualifier Description
HF	Field parameter with a holding time of 15 minutes. Test performed by laboratory at client's request.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

QC Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Method: 9056A - Anions, Ion Chromatography

Lab Sample ID: MB 310-235211/3
Matrix: Water
Analysis Batch: 235211

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	<0.29		1.0	0.29	mg/L			04/08/19 17:19	1
Fluoride	<0.045		0.10	0.045	mg/L			04/08/19 17:19	1
Sulfate	<0.35		1.0	0.35	mg/L			04/08/19 17:19	1

Lab Sample ID: LCS 310-235211/4
Matrix: Water
Analysis Batch: 235211

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Chloride	7.50	7.43		mg/L		99	90 - 110
Fluoride	1.50	1.50		mg/L		100	90 - 110
Sulfate	7.50	7.62		mg/L		102	90 - 110

Method: 6020A - Metals (ICP/MS)

Lab Sample ID: MB 310-234948/1-A
Matrix: Water
Analysis Batch: 236393

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 234948

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		04/08/19 08:00	04/18/19 18:35	1
Arsenic	<0.75		2.0	0.75	ug/L		04/08/19 08:00	04/18/19 18:35	1
Barium	<0.84		2.0	0.84	ug/L		04/08/19 08:00	04/18/19 18:35	1
Beryllium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 18:35	1
Cadmium	<0.077		0.50	0.077	ug/L		04/08/19 08:00	04/18/19 18:35	1
Calcium	<0.10		0.50	0.10	mg/L		04/08/19 08:00	04/18/19 18:35	1
Chromium	<0.98		5.0	0.98	ug/L		04/08/19 08:00	04/18/19 18:35	1
Cobalt	<0.091		0.50	0.091	ug/L		04/08/19 08:00	04/18/19 18:35	1
Lead	<0.27		0.50	0.27	ug/L		04/08/19 08:00	04/18/19 18:35	1
Lithium	<2.7		10	2.7	ug/L		04/08/19 08:00	04/18/19 18:35	1
Selenium	<1.0		5.0	1.0	ug/L		04/08/19 08:00	04/18/19 18:35	1
Thallium	<0.27		1.0	0.27	ug/L		04/08/19 08:00	04/18/19 18:35	1

Lab Sample ID: MB 310-234948/1-A
Matrix: Water
Analysis Batch: 236650

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 234948

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Boron	<110		200	110	ug/L		04/08/19 08:00	04/19/19 16:04	1
Molybdenum	<1.1		2.0	1.1	ug/L		04/08/19 08:00	04/19/19 16:04	1

Lab Sample ID: LCS 310-234948/2-A
Matrix: Water
Analysis Batch: 236393

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 234948

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Antimony	20.0	19.6		ug/L		98	80 - 120
Arsenic	40.0	43.8		ug/L		109	80 - 120
Barium	40.0	40.2		ug/L		100	80 - 120
Beryllium	20.0	20.2		ug/L		101	80 - 120

Method: 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: LCS 310-234948/2-A | **Client Sample ID: Lab Control Sample**
Matrix: Water | **Prep Type: Total/NA**
Analysis Batch: 236393 | **Prep Batch: 234948**

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Cadmium	20.0	20.2		ug/L		101	80 - 120
Calcium	2.00	1.92		mg/L		96	80 - 120
Chromium	40.0	39.5		ug/L		99	80 - 120
Cobalt	20.0	19.3		ug/L		96	80 - 120
Lead	20.0	20.5		ug/L		103	80 - 120
Lithium	100	104		ug/L		104	80 - 120
Selenium	40.0	37.8		ug/L		94	80 - 120
Thallium	16.0	16.2		ug/L		101	80 - 120

Lab Sample ID: LCS 310-234948/2-A | **Client Sample ID: Lab Control Sample**
Matrix: Water | **Prep Type: Total/NA**
Analysis Batch: 236650 | **Prep Batch: 234948**

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Boron	880	797		ug/L		91	80 - 120
Molybdenum	40.0	39.4		ug/L		99	80 - 120

Lab Sample ID: 310-152684-1 MS | **Client Sample ID: MW 301**
Matrix: Ground Water | **Prep Type: Total/NA**
Analysis Batch: 236393 | **Prep Batch: 234948**

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Antimony	<0.53		20.0	20.1		ug/L		101	75 - 125
Arsenic	42		40.0	85.7		ug/L		109	75 - 125
Barium	380		40.0	429	4	ug/L		113	75 - 125
Beryllium	<0.27		20.0	19.9		ug/L		99	75 - 125
Cadmium	<0.077		20.0	19.7		ug/L		99	75 - 125
Calcium	150		2.00	159	4	mg/L		196	75 - 125
Chromium	<0.98		40.0	37.6		ug/L		94	75 - 125
Cobalt	0.44	J	20.0	19.1		ug/L		93	75 - 125
Lead	<0.27		20.0	19.3		ug/L		96	75 - 125
Lithium	13		100	116		ug/L		104	75 - 125
Selenium	<1.0		40.0	38.8		ug/L		97	75 - 125
Thallium	<0.27		16.0	14.8		ug/L		92	75 - 125

Lab Sample ID: 310-152684-1 MS | **Client Sample ID: MW 301**
Matrix: Ground Water | **Prep Type: Total/NA**
Analysis Batch: 236393 | **Prep Batch: 234948**

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Boron	12000		880	13100	4	ug/L		124	75 - 125

Lab Sample ID: 310-152684-1 MS | **Client Sample ID: MW 301**
Matrix: Ground Water | **Prep Type: Total/NA**
Analysis Batch: 236650 | **Prep Batch: 234948**

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Molybdenum	77		40.0	119		ug/L		105	75 - 125

Method: 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: 310-152684-1 MSD
Matrix: Ground Water
Analysis Batch: 236393

Client Sample ID: MW 301
Prep Type: Total/NA
Prep Batch: 234948

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Antimony	<0.53		20.0	20.3		ug/L		102	75 - 125	1	20
Arsenic	42		40.0	85.9		ug/L		109	75 - 125	0	20
Barium	380		40.0	426	4	ug/L		106	75 - 125	1	20
Beryllium	<0.27		20.0	20.2		ug/L		101	75 - 125	2	20
Cadmium	<0.077		20.0	20.0		ug/L		100	75 - 125	1	20
Calcium	150		2.00	161	4	mg/L		288	75 - 125	1	20
Chromium	<0.98		40.0	37.8		ug/L		94	75 - 125	1	20
Cobalt	0.44	J	20.0	19.4		ug/L		95	75 - 125	1	20
Lead	<0.27		20.0	19.3		ug/L		96	75 - 125	0	20
Lithium	13		100	115		ug/L		102	75 - 125	1	20
Selenium	<1.0		40.0	39.8		ug/L		100	75 - 125	3	20
Thallium	<0.27		16.0	14.7		ug/L		92	75 - 125	0	20

Lab Sample ID: 310-152684-1 MSD
Matrix: Ground Water
Analysis Batch: 236393

Client Sample ID: MW 301
Prep Type: Total/NA
Prep Batch: 234948

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Boron	12000		880	13500	4	ug/L		172	75 - 125	3	20

Lab Sample ID: 310-152684-1 MSD
Matrix: Ground Water
Analysis Batch: 236650

Client Sample ID: MW 301
Prep Type: Total/NA
Prep Batch: 234948

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Molybdenum	77		40.0	117		ug/L		99	75 - 125	2	20

Lab Sample ID: 310-152684-11 DU
Matrix: Ground Water
Analysis Batch: 236393

Client Sample ID: MW 311
Prep Type: Total/NA
Prep Batch: 234948

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Antimony	<0.53		<0.53		ug/L		NC	20
Arsenic	19		18.5		ug/L		1	20
Barium	280		285		ug/L		0.3	20
Beryllium	<0.27		<0.27		ug/L		NC	20
Cadmium	<0.077		<0.077		ug/L		NC	20
Calcium	200		197		mg/L		0.8	20
Chromium	<0.98		<0.98		ug/L		NC	20
Cobalt	0.45	J	0.445	J	ug/L		2	20
Lead	0.37	J	0.397	J	ug/L		7	20
Lithium	<2.7		<2.7		ug/L		NC	20
Selenium	<1.0		<1.0		ug/L		NC	20
Thallium	<0.27		<0.27		ug/L		NC	20

Method: 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: 310-152684-11 DU
Matrix: Ground Water
Analysis Batch: 236650

Client Sample ID: MW 311
Prep Type: Total/NA
Prep Batch: 234948

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Boron	1800		1810		ug/L		0.8	20
Molybdenum	8.5		8.51		ug/L		0.09	20

Method: 7470A - Mercury (CVAA)

Lab Sample ID: MB 310-235138/1-A
Matrix: Water
Analysis Batch: 235380

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 235138

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		04/09/19 09:47	04/10/19 13:00	1

Lab Sample ID: LCS 310-235138/2-A
Matrix: Water
Analysis Batch: 235380

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 235138

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Mercury	1.67	1.73		ug/L		104	80 - 120

Lab Sample ID: 310-152684-2 MS
Matrix: Ground Water
Analysis Batch: 235380

Client Sample ID: MW 302
Prep Type: Total/NA
Prep Batch: 235138

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Mercury	<0.10		1.67	1.75		ug/L		105	80 - 120

Lab Sample ID: 310-152684-2 MSD
Matrix: Ground Water
Analysis Batch: 235380

Client Sample ID: MW 302
Prep Type: Total/NA
Prep Batch: 235138

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Mercury	<0.10		1.67	1.75		ug/L		105	80 - 120	1	20

Method: SM 2540C - Solids, Total Dissolved (TDS)

Lab Sample ID: MB 310-234998/1
Matrix: Water
Analysis Batch: 234998

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	<30.0		30.0		mg/L			04/08/19 11:48	1

Lab Sample ID: LCS 310-234998/2
Matrix: Water
Analysis Batch: 234998

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Total Dissolved Solids	1000	1006		mg/L		101	90 - 110

Method: SM 2540C - Solids, Total Dissolved (TDS) (Continued)

Lab Sample ID: MB 310-235152/1
Matrix: Water
Analysis Batch: 235152

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	<30.0		30.0		mg/L			04/09/19 10:18	1

Lab Sample ID: LCS 310-235152/2
Matrix: Water
Analysis Batch: 235152

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Total Dissolved Solids	1000	1008		mg/L		101	90 - 110

Method: SM 4500 H+ B - pH

Lab Sample ID: LCS 310-234752/1
Matrix: Water
Analysis Batch: 234752

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
pH	7.00	7.0		SU		99	98 - 102

Lab Sample ID: 310-152684-5 DU
Matrix: Ground Water
Analysis Batch: 234752

Client Sample ID: MW 305
Prep Type: Total/NA

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
pH	7.4	HF	7.3		SU		0.4	20

HPLC/IC

Analysis Batch: 235211

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-1	MW 301	Total/NA	Ground Water	9056A	
310-152684-2	MW 302	Total/NA	Ground Water	9056A	
310-152684-2	MW 302	Total/NA	Ground Water	9056A	
310-152684-3	MW 303	Total/NA	Ground Water	9056A	
310-152684-4	MW 304	Total/NA	Ground Water	9056A	
310-152684-5	MW 305	Total/NA	Ground Water	9056A	
310-152684-6	MW 306	Total/NA	Ground Water	9056A	
310-152684-7	MW 307	Total/NA	Ground Water	9056A	
310-152684-8	MW 308	Total/NA	Ground Water	9056A	
310-152684-9	MW 309	Total/NA	Ground Water	9056A	
310-152684-10	MW 310	Total/NA	Ground Water	9056A	
310-152684-11	MW 311	Total/NA	Ground Water	9056A	
310-152684-12	Field Blank	Total/NA	Ground Water	9056A	
MB 310-235211/3	Method Blank	Total/NA	Water	9056A	
LCS 310-235211/4	Lab Control Sample	Total/NA	Water	9056A	

Metals

Prep Batch: 234948

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-1	MW 301	Total/NA	Ground Water	3010A	
310-152684-2	MW 302	Total/NA	Ground Water	3010A	
310-152684-3	MW 303	Total/NA	Ground Water	3010A	
310-152684-4	MW 304	Total/NA	Ground Water	3010A	
310-152684-5	MW 305	Total/NA	Ground Water	3010A	
310-152684-6	MW 306	Total/NA	Ground Water	3010A	
310-152684-7	MW 307	Total/NA	Ground Water	3010A	
310-152684-8	MW 308	Total/NA	Ground Water	3010A	
310-152684-9	MW 309	Total/NA	Ground Water	3010A	
310-152684-10	MW 310	Total/NA	Ground Water	3010A	
310-152684-11	MW 311	Total/NA	Ground Water	3010A	
310-152684-12	Field Blank	Total/NA	Ground Water	3010A	
MB 310-234948/1-A	Method Blank	Total/NA	Water	3010A	
LCS 310-234948/2-A	Lab Control Sample	Total/NA	Water	3010A	
310-152684-1 MS	MW 301	Total/NA	Ground Water	3010A	
310-152684-1 MSD	MW 301	Total/NA	Ground Water	3010A	
310-152684-11 DU	MW 311	Total/NA	Ground Water	3010A	

Prep Batch: 235138

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-1	MW 301	Total/NA	Ground Water	7470A	
310-152684-2	MW 302	Total/NA	Ground Water	7470A	
310-152684-3	MW 303	Total/NA	Ground Water	7470A	
310-152684-4	MW 304	Total/NA	Ground Water	7470A	
310-152684-5	MW 305	Total/NA	Ground Water	7470A	
310-152684-6	MW 306	Total/NA	Ground Water	7470A	
310-152684-7	MW 307	Total/NA	Ground Water	7470A	
310-152684-8	MW 308	Total/NA	Ground Water	7470A	
310-152684-9	MW 309	Total/NA	Ground Water	7470A	
310-152684-10	MW 310	Total/NA	Ground Water	7470A	
310-152684-11	MW 311	Total/NA	Ground Water	7470A	

Metals (Continued)

Prep Batch: 235138 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-12	Field Blank	Total/NA	Ground Water	7470A	
MB 310-235138/1-A	Method Blank	Total/NA	Water	7470A	
LCS 310-235138/2-A	Lab Control Sample	Total/NA	Water	7470A	
310-152684-2 MS	MW 302	Total/NA	Ground Water	7470A	
310-152684-2 MSD	MW 302	Total/NA	Ground Water	7470A	

Analysis Batch: 235380

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-1	MW 301	Total/NA	Ground Water	7470A	235138
310-152684-2	MW 302	Total/NA	Ground Water	7470A	235138
310-152684-3	MW 303	Total/NA	Ground Water	7470A	235138
310-152684-4	MW 304	Total/NA	Ground Water	7470A	235138
310-152684-5	MW 305	Total/NA	Ground Water	7470A	235138
310-152684-6	MW 306	Total/NA	Ground Water	7470A	235138
310-152684-7	MW 307	Total/NA	Ground Water	7470A	235138
310-152684-8	MW 308	Total/NA	Ground Water	7470A	235138
310-152684-9	MW 309	Total/NA	Ground Water	7470A	235138
310-152684-10	MW 310	Total/NA	Ground Water	7470A	235138
310-152684-11	MW 311	Total/NA	Ground Water	7470A	235138
310-152684-12	Field Blank	Total/NA	Ground Water	7470A	235138
MB 310-235138/1-A	Method Blank	Total/NA	Water	7470A	235138
LCS 310-235138/2-A	Lab Control Sample	Total/NA	Water	7470A	235138
310-152684-2 MS	MW 302	Total/NA	Ground Water	7470A	235138
310-152684-2 MSD	MW 302	Total/NA	Ground Water	7470A	235138

Analysis Batch: 236393

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-1	MW 301	Total/NA	Ground Water	6020A	234948
310-152684-1	MW 301	Total/NA	Ground Water	6020A	234948
310-152684-2	MW 302	Total/NA	Ground Water	6020A	234948
310-152684-2	MW 302	Total/NA	Ground Water	6020A	234948
310-152684-3	MW 303	Total/NA	Ground Water	6020A	234948
310-152684-3	MW 303	Total/NA	Ground Water	6020A	234948
310-152684-4	MW 304	Total/NA	Ground Water	6020A	234948
310-152684-4	MW 304	Total/NA	Ground Water	6020A	234948
310-152684-5	MW 305	Total/NA	Ground Water	6020A	234948
310-152684-6	MW 306	Total/NA	Ground Water	6020A	234948
310-152684-7	MW 307	Total/NA	Ground Water	6020A	234948
310-152684-8	MW 308	Total/NA	Ground Water	6020A	234948
310-152684-9	MW 309	Total/NA	Ground Water	6020A	234948
310-152684-10	MW 310	Total/NA	Ground Water	6020A	234948
310-152684-11	MW 311	Total/NA	Ground Water	6020A	234948
310-152684-12	Field Blank	Total/NA	Ground Water	6020A	234948
MB 310-234948/1-A	Method Blank	Total/NA	Water	6020A	234948
LCS 310-234948/2-A	Lab Control Sample	Total/NA	Water	6020A	234948
310-152684-1 MS	MW 301	Total/NA	Ground Water	6020A	234948
310-152684-1 MS	MW 301	Total/NA	Ground Water	6020A	234948
310-152684-1 MSD	MW 301	Total/NA	Ground Water	6020A	234948
310-152684-1 MSD	MW 301	Total/NA	Ground Water	6020A	234948
310-152684-11 DU	MW 311	Total/NA	Ground Water	6020A	234948

Metals

Analysis Batch: 236650

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-1	MW 301	Total/NA	Ground Water	6020A	234948
310-152684-2	MW 302	Total/NA	Ground Water	6020A	234948
310-152684-3	MW 303	Total/NA	Ground Water	6020A	234948
310-152684-4	MW 304	Total/NA	Ground Water	6020A	234948
310-152684-5	MW 305	Total/NA	Ground Water	6020A	234948
310-152684-6	MW 306	Total/NA	Ground Water	6020A	234948
310-152684-7	MW 307	Total/NA	Ground Water	6020A	234948
310-152684-8	MW 308	Total/NA	Ground Water	6020A	234948
310-152684-9	MW 309	Total/NA	Ground Water	6020A	234948
310-152684-10	MW 310	Total/NA	Ground Water	6020A	234948
310-152684-11	MW 311	Total/NA	Ground Water	6020A	234948
310-152684-12	Field Blank	Total/NA	Ground Water	6020A	234948
MB 310-234948/1-A	Method Blank	Total/NA	Water	6020A	234948
LCS 310-234948/2-A	Lab Control Sample	Total/NA	Water	6020A	234948
310-152684-1 MS	MW 301	Total/NA	Ground Water	6020A	234948
310-152684-1 MSD	MW 301	Total/NA	Ground Water	6020A	234948
310-152684-11 DU	MW 311	Total/NA	Ground Water	6020A	234948

General Chemistry

Analysis Batch: 234752

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-1	MW 301	Total/NA	Ground Water	SM 4500 H+ B	
310-152684-2	MW 302	Total/NA	Ground Water	SM 4500 H+ B	
310-152684-3	MW 303	Total/NA	Ground Water	SM 4500 H+ B	
310-152684-4	MW 304	Total/NA	Ground Water	SM 4500 H+ B	
310-152684-5	MW 305	Total/NA	Ground Water	SM 4500 H+ B	
310-152684-6	MW 306	Total/NA	Ground Water	SM 4500 H+ B	
310-152684-7	MW 307	Total/NA	Ground Water	SM 4500 H+ B	
310-152684-8	MW 308	Total/NA	Ground Water	SM 4500 H+ B	
310-152684-9	MW 309	Total/NA	Ground Water	SM 4500 H+ B	
310-152684-10	MW 310	Total/NA	Ground Water	SM 4500 H+ B	
310-152684-11	MW 311	Total/NA	Ground Water	SM 4500 H+ B	
310-152684-12	Field Blank	Total/NA	Ground Water	SM 4500 H+ B	
LCS 310-234752/1	Lab Control Sample	Total/NA	Water	SM 4500 H+ B	
310-152684-5 DU	MW 305	Total/NA	Ground Water	SM 4500 H+ B	

Analysis Batch: 234998

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-1	MW 301	Total/NA	Ground Water	SM 2540C	
310-152684-2	MW 302	Total/NA	Ground Water	SM 2540C	
310-152684-3	MW 303	Total/NA	Ground Water	SM 2540C	
310-152684-4	MW 304	Total/NA	Ground Water	SM 2540C	
310-152684-5	MW 305	Total/NA	Ground Water	SM 2540C	
MB 310-234998/1	Method Blank	Total/NA	Water	SM 2540C	
LCS 310-234998/2	Lab Control Sample	Total/NA	Water	SM 2540C	

Analysis Batch: 235152

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-6	MW 306	Total/NA	Ground Water	SM 2540C	
310-152684-7	MW 307	Total/NA	Ground Water	SM 2540C	

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

QC Association Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

General Chemistry (Continued)

Analysis Batch: 235152 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-8	MW 308	Total/NA	Ground Water	SM 2540C	
310-152684-9	MW 309	Total/NA	Ground Water	SM 2540C	
310-152684-10	MW 310	Total/NA	Ground Water	SM 2540C	
310-152684-11	MW 311	Total/NA	Ground Water	SM 2540C	
310-152684-12	Field Blank	Total/NA	Ground Water	SM 2540C	
MB 310-235152/1	Method Blank	Total/NA	Water	SM 2540C	
LCS 310-235152/2	Lab Control Sample	Total/NA	Water	SM 2540C	

Field Service / Mobile Lab

Analysis Batch: 235149

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-1	MW 301	Total/NA	Ground Water	Field Sampling	
310-152684-2	MW 302	Total/NA	Ground Water	Field Sampling	
310-152684-3	MW 303	Total/NA	Ground Water	Field Sampling	
310-152684-4	MW 304	Total/NA	Ground Water	Field Sampling	
310-152684-5	MW 305	Total/NA	Ground Water	Field Sampling	
310-152684-6	MW 306	Total/NA	Ground Water	Field Sampling	
310-152684-7	MW 307	Total/NA	Ground Water	Field Sampling	
310-152684-8	MW 308	Total/NA	Ground Water	Field Sampling	
310-152684-9	MW 309	Total/NA	Ground Water	Field Sampling	
310-152684-10	MW 310	Total/NA	Ground Water	Field Sampling	
310-152684-11	MW 311	Total/NA	Ground Water	Field Sampling	

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 301
Date Collected: 04/03/19 14:20
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-1
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	235211	04/08/19 20:30	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 18:41	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		10	236393	04/18/19 20:33	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236650	04/19/19 16:11	SAD	TAL CF
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:04	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	234998	04/08/19 11:48	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 00:33	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	235149	04/03/19 14:20	ANO	TAL CF

Client Sample ID: MW 302
Date Collected: 04/03/19 15:22
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-2
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	235211	04/08/19 20:43	MLU	TAL CF
Total/NA	Analysis	9056A		20	235211	04/09/19 08:59	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 18:51	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		10	236393	04/18/19 20:43	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236650	04/19/19 16:21	SAD	TAL CF
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:06	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	234998	04/08/19 11:48	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 00:36	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	235149	04/03/19 15:22	ANO	TAL CF

Client Sample ID: MW 303
Date Collected: 04/03/19 16:02
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-3
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	235211	04/08/19 20:57	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 18:54	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		10	236393	04/18/19 20:47	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236650	04/19/19 16:24	SAD	TAL CF

Lab Chronicle

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 303

Date Collected: 04/03/19 16:02
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-3
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:17	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	234998	04/08/19 11:48	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 00:38	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	235149	04/03/19 16:02	ANO	TAL CF

Client Sample ID: MW 304

Date Collected: 04/03/19 17:00
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-4
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	235211	04/08/19 21:24	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 18:58	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		10	236393	04/18/19 20:50	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236650	04/19/19 16:27	SAD	TAL CF
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:19	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	234998	04/08/19 11:48	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 00:40	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	235149	04/03/19 17:00	ANO	TAL CF

Client Sample ID: MW 305

Date Collected: 04/03/19 13:16
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-5
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	235211	04/08/19 21:51	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 19:11	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236650	04/19/19 16:31	SAD	TAL CF
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:21	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	234998	04/08/19 11:48	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 00:46	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	235149	04/03/19 13:16	ANO	TAL CF

Lab Chronicle

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 306

Date Collected: 04/03/19 11:22
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-6
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	235211	04/08/19 22:18	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 19:14	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236650	04/19/19 16:44	SAD	TAL CF
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:23	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	235152	04/09/19 10:18	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 00:50	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	235149	04/03/19 11:22	ANO	TAL CF

Client Sample ID: MW 307

Date Collected: 04/03/19 12:05
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-7
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	235211	04/08/19 23:13	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 19:17	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236650	04/19/19 16:47	SAD	TAL CF
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:25	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	235152	04/09/19 10:18	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 00:51	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	235149	04/03/19 12:05	ANO	TAL CF

Client Sample ID: MW 308

Date Collected: 04/03/19 10:33
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-8
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	235211	04/08/19 23:26	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 19:47	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		2	236650	04/19/19 16:51	SAD	TAL CF
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:27	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	235152	04/09/19 10:18	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 00:53	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	235149	04/03/19 10:33	ANO	TAL CF

Lab Chronicle

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: MW 309

Date Collected: 04/04/19 10:33
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-9
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	235211	04/08/19 23:40	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 19:51	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		2	236650	04/19/19 16:54	SAD	TAL CF
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:29	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	235152	04/09/19 10:18	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 00:55	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	235149	04/04/19 10:33	ANO	TAL CF

Client Sample ID: MW 310

Date Collected: 04/04/19 08:50
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-10
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	235211	04/08/19 23:54	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 19:54	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236650	04/19/19 16:57	SAD	TAL CF
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:32	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	235152	04/09/19 10:18	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 00:57	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	235149	04/04/19 08:50	ANO	TAL CF

Client Sample ID: MW 311

Date Collected: 04/04/19 09:34
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-11
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	235211	04/09/19 00:07	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 19:57	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236650	04/19/19 17:01	SAD	TAL CF
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:34	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	235152	04/09/19 10:18	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 00:59	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	235149	04/04/19 09:34	ANO	TAL CF

Lab Chronicle

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Client Sample ID: Field Blank

Date Collected: 04/03/19 13:25
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-12

Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		1	235211	04/09/19 00:21	MLU	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236393	04/18/19 20:04	SAD	TAL CF
Total/NA	Prep	3010A			234948	04/08/19 08:00	HED	TAL CF
Total/NA	Analysis	6020A		1	236650	04/19/19 17:07	SAD	TAL CF
Total/NA	Prep	7470A			235138	04/09/19 09:47	JNR	TAL CF
Total/NA	Analysis	7470A		1	235380	04/10/19 13:36	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	235152	04/09/19 10:18	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	234752	04/05/19 01:06	JMH	TAL CF

Laboratory References:

TAL CF = Eurofins TestAmerica, Cedar Falls, 3019 Venture Way, Cedar Falls, IA 50613, TEL (319)277-2401

Accreditation/Certification Summary

Laboratory: Eurofins TestAmerica, Cedar Falls

The accreditations/certifications listed below are applicable to this report.

Authority	Program	EPA Region	Identification Number	Expiration Date
Iowa	State Program	7	007	12-01-19

Method Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Method	Method Description	Protocol	Laboratory
9056A	Anions, Ion Chromatography	SW846	TAL CF
6020A	Metals (ICP/MS)	SW846	TAL CF
7470A	Mercury (CVAA)	SW846	TAL CF
SM 2540C	Solids, Total Dissolved (TDS)	SM	TAL CF
SM 4500 H+ B	pH	SM	TAL CF
Field Sampling	Field Sampling	EPA	TAL CF
3010A	Preparation, Total Metals	SW846	TAL CF
7470A	Preparation, Mercury	SW846	TAL CF

Protocol References:

EPA = US Environmental Protection Agency

SM = "Standard Methods For The Examination Of Water And Wastewater"

SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

Laboratory References:

TAL CF = Eurofins TestAmerica, Cedar Falls, 3019 Venture Way, Cedar Falls, IA 50613, TEL (319)277-2401

Table 1. Sampling Points and Parameters - CCR Rule Sampling Program
Groundwater Monitoring - Burlington Generating Station / SCS Engineers Project #25215173.10, Task 2

	Parameter	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306	MW-307	MW-308	MW-309	MW-310	MW-311	Field Blank	TOTAL
Appendix III Parameters	Boron	x	x	x	x	x	x	x	x	x	x	x	x	12
	Calcium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Chloride	x	x	x	x	x	x	x	x	x	x	x	x	12
	Fluoride	x	x	x	x	x	x	x	x	x	x	x	x	12
	pH	x	x	x	x	x	x	x	x	x	x	x	x	12
	Sulfate	x	x	x	x	x	x	x	x	x	x	x	x	12
	TDS	x	x	x	x	x	x	x	x	x	x	x	x	12
Appendix IV Parameters	Antimony	x	x	x	x	x	x	x	x	x	x	x	x	12
	Arsenic	x	x	x	x	x	x	x	x	x	x	x	x	12
	Barium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Beryllium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Cadmium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Chromium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Cobalt	x	x	x	x	x	x	x	x	x	x	x	x	12
	Fluoride	x	x	x	x	x	x	x	x	x	x	x	x	12
	Lead	x	x	x	x	x	x	x	x	x	x	x	x	12
	Lithium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Mercury	x	x	x	x	x	x	x	x	x	x	x	x	12
	Molybdenum	x	x	x	x	x	x	x	x	x	x	x	x	12
	Selenium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Thallium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Radium	x	x	x	x	x	x	x	x	x	x	x	x	12
Field Parameters	Groundwater Elevation	x	x	x	x	x	x	x	x	x	x	x		11
	Well Depth	x	x	x	x	x	x	x	x	x	x	x		11
	pH (field)	x	x	x	x	x	x	x	x	x	x	x		11
	Specific Conductance	x	x	x	x	x	x	x	x	x	x	x		11
	Dissolved Oxygen	x	x	x	x	x	x	x	x	x	x	x		11
	ORP	x	x	x	x	x	x	x	x	x	x	x		11
	Temperature	x	x	x	x	x	x	x	x	x	x	x		11
	Turbidity	x	x	x	x	x	x	x	x	x	x	x		11
	Color	x	x	x	x	x	x	x	x	x	x	x		11
	Odor	x	x	x	x	x	x	x	x	x	x	x		11

Notes: All samples are unfiltered (total).

C:\Users\3510med\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Outlook\1WB99N1Q\[Table_

Table 2. Groundwater Monitoring Results - Field Parameters
Burlington Generating Station / SCS Engineers Project No. 25219066
April 2019

Sample	Sample Date/Time	Temperature (Deg. C)	pH (Std. Units)	Dissolved Oxygen (mg/L)	Specific Conductivity (µmhos/cm)	ORP (mV)	Turbidity	Groundwater Elevation (amsl)
MW-301	4/3/2019 1420	12.35	7.53	0.59	1213	-144.7	21.10	528.15
MW-302	4/3/2019 1522	11.41	8.70	0.58	1164	-215.8	18.80	528.21
MW-303	4/3/2019 1602	12.63	7.79	0.67	711	-122.8	18.20	528.22
MW-304	4/3/2019 1700	12.96	8.56	0.39	658	-216.7	6.22	528.27
MW-305	4/3/2019 1316	14.47	7.80	0.59	733	-133.5	3.88	528.36
MW-306	4/3/2019 1122	13.44	6.69	0.69	4711	-92.8	0.81	528.40
MW-307	4/3/2019 1205	13.56	10.39	0.68	500	-167.8	3.10	528.63
MW-308	4/3/2019 1033	14.04	9.97	1.16	681	-142.3	1.66	528.39
MW-309	4/4/2019 1033	12.60	7.45	0.51	997	-99.4	20.1	528.40
MW-310	4/4/2019 0850	10.8	7.84	1.12	1034	-175.8	16.70	528.62
MW-311	4/4/2019 0934	11.41	7.64	0.78	1422	145.8	10.80	528.20

Abbreviations:
mg/L = milligrams per liter amsl = above mean sea level mV = millivolts µmhos/cm = micromohs per cm

Notes: turbidity not measured at MW-310
None

Created by: KAK Date: 8/28/2017
Last revision by: NDK Date: 4/5/2019
Checked by: AJR Date: 4/8/2019

I:\25219066.00\Data and Calculations\Tables\[BGS_CCR_Field_1904.xlsx]GW Field Parameters

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

310-152684 Chain of Custody

Cooler/Sample Receipt and Temperature Log Form

Client Information

Client: SCS Engineers

City/State: CITY Clive STATE IA | Project: Burlington

Receipt Information

Date/Time Received: DATE 4-4-19 TIME 1800 | Received By: LAB

Delivery Type: ☐ UPS ☐ FedEx ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee ☒ Lab Courier ☐ TA Field Services ☐ Client Drop-off ☐ Other:________

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes ☐ No	*If yes:* Cooler ID:	EZ8
Multiple Coolers?	☒ Yes ☐ No	*If yes:* Cooler # 1 of 3	
Cooler Custody Seals Present?	☒ Yes ☐ No	*If yes:* Cooler custody seals intact?	☒ Yes ☐ No
Sample Custody Seals Present?	☐ Yes ☒ No	*If yes:* Sample custody seals intact?	☐ Yes ☐ No
Trip Blank Present?	☐ Yes ☒ No	*If yes:* Which VOA samples are in cooler? ↓	

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:________ ☐ NONE

Thermometer ID: N | Correction Factor (°C): +0.0

• **Temp Blank Temperature** – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): 1.7 | Corrected Temp (°C): 1.7

• **Sample Container Temperature**

Container type(s) used: CONTAINER 1 | CONTAINER 2

Uncorrected Temp (°C): TEMP 1 | TEMP 2 | Corrected Temp (°C): TEMP 1 | TEMP 2

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Place COC scanning label here
214

Cooler/Sample Receipt and Temperature Log Form

Client Information			
Client:	SCS Engineers		
City/State:	CITY Clive	STATE IA	Project: Burlington

Receipt Information			
Date/Time Received:	DATE 4-4-19	TIME 1800	Received By: LAB

Delivery Type: ☐ UPS ☐ FedEx ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee ☒ Lab Courier ☐ TA Field Services ☐ Client Drop-off ☐ Other:____________

Condition of Cooler/Containers			
Sample(s) received in Cooler?	☒ Yes	☐ No	*If yes:* Cooler ID:
Multiple Coolers?	☒ Yes	☐ No	*If yes:* Cooler # 2 of 3
Cooler Custody Seals Present?	☒ Yes	☐ No	*If yes:* Cooler custody seals intact? ☒ Yes ☐ No
Sample Custody Seals Present?	☐ Yes	☒ No	*If yes:* Sample custody seals intact? ☐ Yes ☐ No
Trip Blank Present?	☐ Yes	☒ No	*If yes:* Which VOA samples are in cooler? ↓

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:____________ ☐ NONE

Thermometer ID: N	Correction Factor (°C): +0.0

• Temp Blank Temperature – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): 3.8	Corrected Temp (°C): 3.8

• Sample Container Temperature

Container type(s) used:	CONTAINER 1	CONTAINER 2		
Uncorrected Temp (°C):	TEMP 1	TEMP 2	Corrected Temp (°C):	TEMP 1 / TEMP 2

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
 a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

Document: CF-LG-WI-002
Revision: 24
Date: 03/07/2019

General temperature criteria is 0 to 6°C
Bacteria temperature criteria is 0 to 10°C

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Place COC scanning label here
214

Cooler/Sample Receipt and Temperature Log Form

Client Information

Client: SCS Engineers

City/State: CITY Olive STATE IA | Project: Burlington

Receipt Information

Date/Time Received: DATE 4-4-19 TIME 1800 | Received By: LAB

Delivery Type: ☐ UPS ☐ FedEx ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee
☒ Lab Courier ☐ TA Field Services ☐ Client Drop-off ☐ Other:________

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes ☐ No	*If yes:* Cooler ID: AA-18	
Multiple Coolers?	☒ Yes ☐ No	*If yes:* Cooler # 3 of 3	
Cooler Custody Seals Present?	☒ Yes ☐ No	*If yes:* Cooler custody seals intact?	☒ Yes ☐ No
Sample Custody Seals Present?	☐ Yes ☒ No	*If yes:* Sample custody seals intact?	☐ Yes ☐ No
Trip Blank Present?	☐ Yes ☒ No	*If yes:* Which VOA samples are in cooler? ↓	

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:________ ☐ NONE

Thermometer ID: N | Correction Factor (°C): +0.0

• **Temp Blank Temperature** – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): 4.2 | Corrected Temp (°C): 4.2

• **Sample Container Temperature**

Container type(s) used: CONTAINER 1 CONTAINER 2

Uncorrected Temp (°C): TEMP 1 TEMP 2 | Corrected Temp (°C): TEMP 1 TEMP 2

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

2 1L Nitric, 1 PL 250 Nitric + 1 PL500NT rcvd empty

Document: CF-LG-WI-002
Revision: 24
Date: 03/07/2019

General temperature criteria is 0 to 6°C
Bacteria temperature criteria is 0 to 10°C

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Cedar Falls Division
704 Enterprise Drive
Cedar Falls, IA 50613

Phone 319-277-2401 or 800-750-2401
Fax 319-277-2425

TestAmerica Des Moines SC
214

To assist us in using the proper analytical methods, is this work being conducted for regulatory purposes?
Compliance Monitoring ________

Client Name: SCS Engineers
Client #:
Address: 8450 Hickman Rd Suite 20
City/State/Zip Code: Clive IA
Project Manager:
Email Address:
Telephone Number:
Fax:
Sampler Name: (Print Name) Nick Schemmel
Sampler Signature: [signature]

Project Name: Burlington
Project #: 25216066
Site/Location ID: Burlington
State: IA
Report To:
Invoice To:
Quote #:
PO#:

TAT
___ Standard
___ Rush (surcharges may apply)

Date Needed: ________

Fax Results: Y N
Email Results: Y N

QC Deliverables
___ None
___ Level 2 *(Batch QC)*
___ Level 3
___ Level 4
Other: ________

SAMPLE ID	Date Sampled	Time Sampled	G = Grab, C = Composite	Field Filtered	Matrix (SL - Sludge, DW - Drinking Water, GW - Groundwater, S - Soil/Solid, WW - Wastewater, Specify, Other)	HNO_3	HCl	NaOH	H_2SO_4	Methanol	None	Other (Specify)	Metals	pH	TDS	Chloride/Fluoride/SO4	Radium 226+228						REMARKS
MW 301	4.3.19	1420	G		GW	3					1		X	X	X	X	X						
MW 302	↓	1522	↓		↓	3					1		X	X	X	X	X						
MW 303	↓	1602	↓		↓	3					1		X	X	X	X	X						
MW 304	↓	1700	↓		↓	3					1		X	X	X	X	X						
MW 305	↓	1316	↓		↓	3					1		X	X	X	X	X						
MW 306	↓	1122	↓		↓	3					1		X	X	X	X	X						
MW 307	↓	1205	↓		↓	3					1		X	X	X	X	X						
MW 308	↓	1033	↓		↓	3					1		X	X	X	X	X						
MW 309	4.4.19	1033	↓		↓	3					1		X	X	X	X	X						

Special Instructions:

LABORATORY COMMENTS:

Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Nick Schemmel	4.4.19		[signature]	4.4.19	14:59
			Lindsay Bındl	4.4.19	1800
	~~4.4.19~~				

TAL-0033 (0708)

Page ______ of ______

15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Cedar Falls Division
704 Enterprise Drive
Cedar Falls, IA 50613

Phone 319-277-2401 or 800-750-2401
Fax 319-277-2425

To assist us in using the proper analytical methods, is this work being conducted for regulatory purposes?
Compliance Monitoring ______

TestAmerica Des Moines SC
214

Client Name: SCS Engineers Client #:
Address: 8450 Hickman Rd Suite 20
City/State/Zip Code: Clive IA
Project Manager:
Email Address:
Telephone Number: Fax:
Sampler Name: (Print Name) Nick Schemmel
Sampler Signature:

Project Name: Burlington
Project #: 25216066
Site/Location ID: Burlington State: IA
Report To:
Invoice To:
Quote #: PO#:

TAT
___ Standard
___ Rush (surcharges may apply)
Date Needed:
Fax Results: Y N
Email Results: Y N

QC Deliverables
___ None
___ Level 2 *(Batch QC)*
___ Level 3
___ Level 4
Other: ______

SAMPLE ID	Date Sampled	Time Sampled	G = Grab, C = Composite	Field Filtered	Matrix: SL - Sludge, DW - Drinking Water, GW - Groundwater, S - Soil/Solid, WW - Wastewater, Specify, Other	HNO_3	HCl	NaOH	H_2SO_4	Methanol	None	Other (Specify)	Metals	pH	TDS	Chloride/Fluoride/SO4	Radium 226+228						REMARKS
MW 310	4.4.19	0850	G		GW	3					1		X	X	X	X	X						
MW 311	↓	0934	↓		↓	3					1		X	X	X	X	X						
Field Blank	4.3.19	1325	↓		↓	3					1		X	X	X	X	X						

Special Instructions:

LABORATORY COMMENTS:

Relinquished By	Date	Time	Received By	Date	Time
Nick Schemmel	4.4.19		[signature]	4/4/19	14:59
			Lindsay Brolet	4 4 19	1800

TAL-0033 (0708)

Page ______ of ______

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7/11/2019 (Rev. 1)

15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Temperature readings: ____________________

Client Sample ID	Lab ID	Container Type	Container pH	Preservative Added (mls)	Lot #
MW 301	310-152684-A-1	Plastic 250ml - with Nitric Acid	<2		
MW 301	310-152684-C-1	Plastic 1 liter - Nitric Acid	<2		
MW 301	310-152684-D-1	Plastic 1 liter - Nitric Acid	<2		
MW 302	310-152684-A-2	Plastic 250ml - with Nitric Acid	<2		
MW 302	310-152684-C-2	Plastic 1 liter - Nitric Acid	<2		
MW 302	310-152684-D-2	Plastic 1 liter - Nitric Acid	<2		
MW 303	310-152684-A-3	Plastic 250ml - with Nitric Acid	<2		
MW 303	310-152684-C-3	Plastic 1 liter - Nitric Acid	<2		
MW 303	310-152684-D-3	Plastic 1 liter - Nitric Acid	<2		
MW 304	310-152684-A-4	Plastic 250ml - with Nitric Acid	<2		
MW 304	310-152684-C-4	Plastic 1 liter - Nitric Acid	<2		
MW 304	310-152684-D-4	Plastic 1 liter - Nitric Acid	<2		
MW 305	310-152684-A-5	Plastic 250ml - with Nitric Acid	<2		
MW 305	310-152684-C-5	Plastic 1 liter - Nitric Acid	<2		
MW 305	310-152684-D-5	Plastic 1 liter - Nitric Acid	<2		
MW 306	310-152684-A-6	Plastic 250ml - with Nitric Acid	<2		
MW 306	310-152684-C-6	Plastic 1 liter - Nitric Acid	<2		
MW 306	310-152684-D-6	Plastic 1 liter - Nitric Acid	<2		
MW 307	310-152684-A-7	Plastic 250ml - with Nitric Acid	<2		
MW 307	310-152684-C-7	Plastic 1 liter - Nitric Acid	<2		
MW 307	310-152684-D-7	Plastic 1 liter - Nitric Acid	<2		
MW 308	310-152684-A-8	Plastic 250ml - with Nitric Acid	<2		
MW 308	310-152684-C-8	Plastic 1 liter - Nitric Acid	<2		
MW 308	310-152684-D-8	Plastic 1 liter - Nitric Acid	<2		
MW 309	310-152684-A-9	Plastic 250ml - with Nitric Acid	<2		
MW 309	310-152684-C-9	Plastic 1 liter - Nitric Acid	<2		
MW 309	310-152684-D-9	Plastic 1 liter - Nitric Acid	<2		
MW 310	310-152684-A-10	Plastic 250ml - with Nitric Acid	<2		
MW 310	310-152684-C-10	Plastic 1 liter - Nitric Acid	<2		
MW 310	310-152684-D-10	Plastic 1 liter - Nitric Acid	<2		
MW 311	310-152684-A-11	Plastic 250ml - with Nitric Acid	<2		
MW 311	310-152684-C-11	Plastic 1 liter - Nitric Acid	<2		
MW 311	310-152684-D-11	Plastic 1 liter - Nitric Acid	<2		
Field Blank	310-152684-A-12	Plastic 250ml - with Nitric Acid	<2		
Field Blank	310-152684-C-12	Plastic 1 liter - Nitric Acid	<2		
Field Blank	310-152684-D-12	Plastic 1 liter - Nitric Acid	<2		

Client Sample ID	Lab ID	Container Type	Container pH	Preservative Added (mls)	Lot #

Login Sample Receipt Checklist

Client: SCS Engineers

Job Number: 310-152684-1
SDG Number: 25216066

Login Number: 152684
List Number: 1
Creator: Bovy, Lorrainna L

List Source: Eurofins TestAmerica, Cedar Falls

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Tracer/Carrier Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-1
SDG: 25216066

Method: 903.0 - Radium-226 (GFPC)

Matrix: Ground Water **Prep Type: Total/NA**

Percent Yield (Acceptance Limits)

Lab Sample ID	Client Sample ID	Ba Carrier (40-110)
310-152684-1	MW 301	101
310-152684-2	MW 302	93.8
310-152684-3	MW 303	100
310-152684-4	MW 304	97.5
310-152684-5	MW 305	91.0
310-152684-6	MW 306	99.2
310-152684-7	MW 307	94.9
310-152684-8	MW 308	98.9
310-152684-9	MW 309	98.6
310-152684-10	MW 310	100
310-152684-11	MW 311	100
310-152684-12	Field Blank	93.8

Tracer/Carrier Legend

Ba Carrier = Ba Carrier

Method: 903.0 - Radium-226 (GFPC)

Matrix: Water **Prep Type: Total/NA**

Percent Yield (Acceptance Limits)

Lab Sample ID	Client Sample ID	Ba Carrier (40-110)
LCS 160-424079/1-A	Lab Control Sample	110
LCS 160-424949/1-A	Lab Control Sample	101
LCSD 160-424079/2-A	Lab Control Sample Dup	106
LCSD 160-424949/2-A	Lab Control Sample Dup	103
MB 160-424079/23-A	Method Blank	104
MB 160-424949/23-A	Method Blank	109

Tracer/Carrier Legend

Ba Carrier = Ba Carrier

Method: 904.0 - Radium-228 (GFPC)

Matrix: Ground Water **Prep Type: Total/NA**

Percent Yield (Acceptance Limits)

Lab Sample ID	Client Sample ID	Ba Carrier (40-110)	Y Carrier (40-110)
310-152684-1	MW 301	101	80.0
310-152684-2	MW 302	93.8	80.4
310-152684-3	MW 303	100	73.3
310-152684-4	MW 304	97.5	76.6
310-152684-5	MW 305	91.0	75.1
310-152684-6	MW 306	99.2	79.3
310-152684-7	MW 307	94.9	90.8
310-152684-8	MW 308	98.9	92.3
310-152684-9	MW 309	98.6	88.6
310-152684-10	MW 310	100	90.8
310-152684-11	MW 311	100	91.2
310-152684-12	Field Blank	93.8	93.5

Tracer/Carrier Legend

Method: 904.0 - Radium-228 (GFPC)

Matrix: Water **Prep Type: Total/NA**

		Percent Yield (Acceptance Limits)	
Lab Sample ID	Client Sample ID	Ba Carrier (40-110)	Y Carrier (40-110)
LCS 160-424232/1-A	Lab Control Sample	110	72.1
LCS 160-424953/1-A	Lab Control Sample	101	97.6
LCSD 160-424232/2-A	Lab Control Sample Dup	106	78.9
LCSD 160-424953/2-A	Lab Control Sample Dup	103	92.3
MB 160-424232/23-A	Method Blank	104	80.0
MB 160-424953/23-A	Method Blank	109	86.4

Tracer/Carrier Legend

Ba Carrier = Ba Carrier
Y Carrier = Y Carrier

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

ANALYTICAL REPORT

Eurofins TestAmerica, Cedar Falls
3019 Venture Way
Cedar Falls, IA 50613
Tel: (319)277-2401

Laboratory Job ID: 310-152684-2
Laboratory Sample Delivery Group: 25216066
Client Project/Site: Burlington - 25216066

For:
SCS Engineers
2830 Dairy Drive
Madison, Wisconsin 53718

Attn: Meghan Blodgett

Authorized for release by:
7/11/2019 9:22:50 AM

Sandie Fredrick, Project Manager II
(920)261-1660
sandie.fredrick@testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Case Narrative

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Job ID: 310-152684-2

Laboratory: Eurofins TestAmerica, Cedar Falls

Narrative

Job Narrative
310-152684-2

Comments
No additional comments.

Receipt
The samples were received on 4/4/2019 6:00 PM; the samples arrived in good condition, properly preserved and, where required, on ice. The temperatures of the 3 coolers at receipt time were 1.7º C, 3.8º C and 4.2º C.

RAD
Method(s) 903.0, 9315: Ra-226 Prep Batch 160-424949
Any minimum detectable concentration (MDC), critical value (DLC), or Safe Drinking Water Act detection limit (SDWA DL) is sample-specific unless otherwise stated elsewhere in this narrative.

Radiochemistry sample results are reported with the count date/time applied as the Activity Reference Date.
MW 307 (310-152684-7), MW 308 (310-152684-8), MW 309 (310-152684-9), MW 310 (310-152684-10), MW 311 (310-152684-11), Field Blank (310-152684-12), (LCS 160-424949/1-A), (LCSD 160-424949/2-A) and (MB 160-424949/23-A)

Method(s) 903.0: Ra-226 Prep Batch 160-424079
Any minimum detectable concentration (MDC), critical value (DLC), or Safe Drinking Water Act detection limit (SDWA DL) is sample-specific unless otherwise stated elsewhere in this narrative.

Radiochemistry sample results are reported with the count date/time applied as the Activity Reference Date.
MW 301 (310-152684-1), MW 302 (310-152684-2), MW 303 (310-152684-3), MW 304 (310-152684-4), MW 305 (310-152684-5), MW 306 (310-152684-6), (LCS 160-424079/1-A), (LCSD 160-424079/2-A) and (MB 160-424079/23-A)

Method(s) 904.0: Ra-228 Prep Batch 160-424232
Any minimum detectable concentration (MDC), critical value (DLC), or Safe Drinking Water Act detection limit (SDWA DL) is sample-specific unless otherwise stated elsewhere in this narrative.

Radiochemistry sample results are reported with the count date/time applied as the Activity Reference Date.
MW 301 (310-152684-1), MW 302 (310-152684-2), MW 303 (310-152684-3), MW 304 (310-152684-4), MW 305 (310-152684-5), MW 306 (310-152684-6), (LCS 160-424232/1-A), (LCSD 160-424232/2-A) and (MB 160-424232/23-A)

Method(s) 904.0, 9320: Ra-228 Prep Batch 160-424953
Any minimum detectable concentration (MDC), critical value (DLC), or Safe Drinking Water Act detection limit (SDWA DL) is sample-specific unless otherwise stated elsewhere in this narrative.

Radiochemistry sample results are reported with the count date/time applied as the Activity Reference Date.
MW 307 (310-152684-7), MW 308 (310-152684-8), MW 309 (310-152684-9), MW 310 (310-152684-10), MW 311 (310-152684-11), Field Blank (310-152684-12), (LCS 160-424953/1-A), (LCSD 160-424953/2-A) and (MB 160-424953/23-A)

Method(s) PrecSep_0: Radium-228 Prep Batch 424232:
Insufficient sample volume was available to perform a sample duplicate for the following samples: MW 301 (310-152684-1), MW 302 (310-152684-2), MW 303 (310-152684-3), MW 304 (310-152684-4), MW 305 (310-152684-5) and MW 306 (310-152684-6). A laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) were prepared instead to demonstrate batch precision.

Method(s) PrecSep_0: Radium 228 Prep Batch 160-424953:
Insufficient sample volume was available to perform a sample duplicate for the following samples: MW 307 (310-152684-7), MW 308 (310-152684-8), MW 309 (310-152684-9), MW 310 (310-152684-10), MW 311 (310-152684-11) and Field Blank (310-152684-12). A laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) were prepared instead to demonstrate batch precision.

Method(s) PrecSep-21: Radium-226 Prep Batch 424079:
Insufficient sample volume was available to perform a sample duplicate for the following samples: MW 301 (310-152684-1), MW 302

Job ID: 310-152684-2 (Continued)

Laboratory: Eurofins TestAmerica, Cedar Falls (Continued)

(310-152684-2), MW 303 (310-152684-3), MW 304 (310-152684-4), MW 305 (310-152684-5) and MW 306 (310-152684-6). A laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) were prepared instead to demonstrate batch precision.

Method(s) PrecSep-21: Radium 226 Prep Batch 160-424949:
Insufficient sample volume was available to perform a sample duplicate for the following samples: MW 307 (310-152684-7), MW 308 (310-152684-8), MW 309 (310-152684-9), MW 310 (310-152684-10), MW 311 (310-152684-11) and Field Blank (310-152684-12). A laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) were prepared instead to demonstrate batch precision.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

Sample Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Lab Sample ID	Client Sample ID	Matrix	Collected	Received	Asset ID
310-152684-1	MW 301	Ground Water	04/03/19 14:20	04/04/19 18:00	
310-152684-2	MW 302	Ground Water	04/03/19 15:22	04/04/19 18:00	
310-152684-3	MW 303	Ground Water	04/03/19 16:02	04/04/19 18:00	
310-152684-4	MW 304	Ground Water	04/03/19 17:00	04/04/19 18:00	
310-152684-5	MW 305	Ground Water	04/03/19 13:16	04/04/19 18:00	
310-152684-6	MW 306	Ground Water	04/03/19 11:22	04/04/19 18:00	
310-152684-7	MW 307	Ground Water	04/03/19 12:05	04/04/19 18:00	
310-152684-8	MW 308	Ground Water	04/03/19 10:33	04/04/19 18:00	
310-152684-9	MW 309	Ground Water	04/04/19 10:33	04/04/19 18:00	
310-152684-10	MW 310	Ground Water	04/04/19 08:50	04/04/19 18:00	
310-152684-11	MW 311	Ground Water	04/04/19 09:34	04/04/19 18:00	
310-152684-12	Field Blank	Ground Water	04/03/19 13:25	04/04/19 18:00	

Detection Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 301 — Lab Sample ID: 310-152684-1

No Detections.

Client Sample ID: MW 302 — Lab Sample ID: 310-152684-2

No Detections.

Client Sample ID: MW 303 — Lab Sample ID: 310-152684-3

No Detections.

Client Sample ID: MW 304 — Lab Sample ID: 310-152684-4

No Detections.

Client Sample ID: MW 305 — Lab Sample ID: 310-152684-5

No Detections.

Client Sample ID: MW 306 — Lab Sample ID: 310-152684-6

No Detections.

Client Sample ID: MW 307 — Lab Sample ID: 310-152684-7

No Detections.

Client Sample ID: MW 308 — Lab Sample ID: 310-152684-8

No Detections.

Client Sample ID: MW 309 — Lab Sample ID: 310-152684-9

No Detections.

Client Sample ID: MW 310 — Lab Sample ID: 310-152684-10

No Detections.

Client Sample ID: MW 311 — Lab Sample ID: 310-152684-11

No Detections.

Client Sample ID: Field Blank — Lab Sample ID: 310-152684-12

No Detections.

This Detection Summary does not include radiochemical test results.

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 301
Date Collected: 04/03/19 14:20
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-1
Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.411		0.115	0.121	1.00	0.0740	pCi/L	04/16/19 17:52	05/13/19 06:37	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*101*		*40 - 110*	*04/16/19 17:52*	*05/13/19 06:37*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.736		0.267	0.276	1.00	0.365	pCi/L	04/17/19 10:22	05/06/19 14:59	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*101*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:59*	*1*
Y Carrier	*80.0*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:59*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	1.15		0.291	0.301	5.00	0.365	pCi/L		05/30/19 09:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 302

Date Collected: 04/03/19 15:22
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-2
Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.362**		0.115	0.119	1.00	0.0898	pCi/L	04/16/19 17:52	05/13/19 06:37	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*93.8*		*40 - 110*	*04/16/19 17:52*	*05/13/19 06:37*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	**0.510**		0.262	0.266	1.00	0.387	pCi/L	04/17/19 10:22	05/06/19 14:59	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*93.8*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:59*	*1*
Y Carrier	*80.4*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:59*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**0.872**		0.286	0.291	5.00	0.387	pCi/L		05/30/19 09:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 303
Date Collected: 04/03/19 16:02
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-3
Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.552		0.133	0.142	1.00	0.0875	pCi/L	04/16/19 17:52	05/13/19 06:37	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*100*		*40 - 110*	*04/16/19 17:52*	*05/13/19 06:37*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.703		0.272	0.279	1.00	0.372	pCi/L	04/17/19 10:22	05/06/19 14:59	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*100*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:59*	*1*
Y Carrier	*73.3*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:59*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	1.26		0.303	0.313	5.00	0.372	pCi/L		05/30/19 09:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 304
Date Collected: 04/03/19 17:00
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-4
Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.116**		0.0747	0.0754	1.00	0.101	pCi/L	04/16/19 17:52	05/13/19 06:37	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*97.5*		*40 - 110*	*04/16/19 17:52*	*05/13/19 06:37*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.292	U	0.240	0.241	1.00	0.380	pCi/L	04/17/19 10:22	05/06/19 14:59	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*97.5*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:59*	*1*
Y Carrier	*76.6*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:59*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**0.408**		0.251	0.253	5.00	0.380	pCi/L		05/30/19 09:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 305

Date Collected: 04/03/19 13:16
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-5

Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.154**		0.0830	0.0841	1.00	0.0991	pCi/L	04/16/19 17:52	05/13/19 06:37	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*91.0*		*40 - 110*	*04/16/19 17:52*	*05/13/19 06:37*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.365	U	0.265	0.267	1.00	0.414	pCi/L	04/17/19 10:22	05/06/19 14:59	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*91.0*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:59*	*1*
Y Carrier	*75.1*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:59*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**0.519**		0.278	0.280	5.00	0.414	pCi/L		05/30/19 09:32	1

Eurofins TestAmerica, Cedar Falls

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 306

Date Collected: 04/03/19 11:22
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-6
Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0333	U	0.0586	0.0587	1.00	0.104	pCi/L	04/16/19 17:52	05/13/19 06:38	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*99.2*		*40 - 110*	*04/16/19 17:52*	*05/13/19 06:38*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.132	U	0.213	0.213	1.00	0.360	pCi/L	04/17/19 10:22	05/06/19 14:57	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*99.2*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:57*	*1*
Y Carrier	*79.3*		*40 - 110*	*04/17/19 10:22*	*05/06/19 14:57*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	0.165	U	0.221	0.221	5.00	0.360	pCi/L		05/30/19 09:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 307

Date Collected: 04/03/19 12:05
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-7

Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0752	U	0.0749	0.0752	1.00	0.118	pCi/L	04/22/19 12:18	05/18/19 21:51	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*94.9*		*40 - 110*	*04/22/19 12:18*	*05/18/19 21:51*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	**0.372**		0.219	0.222	1.00	0.329	pCi/L	04/22/19 12:52	05/09/19 08:49	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*94.9*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*
Y Carrier	*90.8*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**0.447**		0.231	0.234	5.00	0.329	pCi/L		05/30/19 09:32	1

Client Sample Results

Client Sample ID: MW 308
Date Collected: 04/03/19 10:33
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-8
Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0363	U	0.0564	0.0565	1.00	0.0979	pCi/L	04/22/19 12:18	05/18/19 21:51	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*98.9*		*40 - 110*	*04/22/19 12:18*	*05/18/19 21:51*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	**0.291**		0.182	0.184	1.00	0.273	pCi/L	04/22/19 12:52	05/09/19 08:49	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*98.9*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*
Y Carrier	*92.3*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**0.328**		0.191	0.192	5.00	0.273	pCi/L		05/30/19 09:32	1

Client Sample ID: MW 309

Date Collected: 04/04/19 10:33
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-9
Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.126**		0.0764	0.0772	1.00	0.0951	pCi/L	04/22/19 12:18	05/18/19 21:52	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*98.6*		*40 - 110*	*04/22/19 12:18*	*05/18/19 21:52*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.295	U	0.223	0.224	1.00	0.351	pCi/L	04/22/19 12:52	05/09/19 08:49	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*98.6*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*
Y Carrier	*88.6*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**0.420**		0.236	0.237	5.00	0.351	pCi/L		05/30/19 09:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 310

Date Collected: 04/04/19 08:50
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-10

Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.471		0.125	0.132	1.00	0.0869	pCi/L	04/22/19 12:18	05/18/19 21:52	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*100*		*40 - 110*	*04/22/19 12:18*	*05/18/19 21:52*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.724		0.240	0.249	1.00	0.311	pCi/L	04/22/19 12:52	05/09/19 08:49	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*100*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*
Y Carrier	*90.8*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	1.19		0.271	0.282	5.00	0.311	pCi/L		05/30/19 09:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 311

Date Collected: 04/04/19 09:34
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-11
Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.198		0.0995	0.101	1.00	0.125	pCi/L	04/22/19 12:18	05/18/19 21:52	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*100*		*40 - 110*	*04/22/19 12:18*	*05/18/19 21:52*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.617		0.228	0.235	1.00	0.307	pCi/L	04/22/19 12:52	05/09/19 08:49	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*100*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*
Y Carrier	*91.2*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	0.815		0.249	0.256	5.00	0.307	pCi/L		05/30/19 09:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: Field Blank

Date Collected: 04/03/19 13:25
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-12

Matrix: Ground Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0144	U	0.0498	0.0498	1.00	0.0971	pCi/L	04/22/19 12:18	05/18/19 21:52	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*93.8*		*40 - 110*	*04/22/19 12:18*	*05/18/19 21:52*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.205	U	0.192	0.193	1.00	0.309	pCi/L	04/22/19 12:52	05/09/19 08:49	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*93.8*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*
Y Carrier	*93.5*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	0.220	U	0.198	0.199	5.00	0.309	pCi/L		05/30/19 09:32	1

Definitions/Glossary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Qualifiers

Rad

Qualifier	Qualifier Description
U	Result is less than the sample detection limit.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

QC Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Method: 903.0 - Radium-226 (GFPC)

Lab Sample ID: MB 160-424079/23-A
Matrix: Water
Analysis Batch: 428063

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 424079

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.05045	U	0.0502	0.0504	1.00	0.0756	pCi/L	04/16/19 17:52	05/13/19 06:39	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*104*		*40 - 110*	*04/16/19 17:52*	*05/13/19 06:39*	*1*

Lab Sample ID: LCS 160-424079/1-A
Matrix: Water
Analysis Batch: 428036

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 424079

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-226	11.4	9.128		0.978	1.00	0.0983	pCi/L	80	75 - 125

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*110*		*40 - 110*

Lab Sample ID: LCSD 160-424079/2-A
Matrix: Water
Analysis Batch: 428036

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 424079

Analyte	Spike Added	LCSD Result	LCSD Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits	RER	RER Limit
Radium-226	11.4	9.623		1.03	1.00	0.132	pCi/L	85	75 - 125	0.25	1

Carrier	*LCSD %Yield*	*LCSD Qualifier*	*Limits*
Ba Carrier	*106*		*40 - 110*

Lab Sample ID: MB 160-424949/23-A
Matrix: Water
Analysis Batch: 429045

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 424949

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.04549	U	0.0674	0.0675	1.00	0.115	pCi/L	04/22/19 12:18	05/18/19 21:52	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*109*		*40 - 110*	*04/22/19 12:18*	*05/18/19 21:52*	*1*

Lab Sample ID: LCS 160-424949/1-A
Matrix: Water
Analysis Batch: 429039

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 424949

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-226	11.4	9.893		1.04	1.00	0.0943	pCi/L	87	75 - 125

QC Sample Results

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Method: 903.0 - Radium-226 (GFPC) (Continued)

Lab Sample ID: LCS 160-424949/1-A
Matrix: Water
Analysis Batch: 429039

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 424949

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*101*		*40 - 110*

Lab Sample ID: LCSD 160-424949/2-A
Matrix: Water
Analysis Batch: 429039

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 424949

Analyte			Spike Added	LCSD Result	LCSD Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits	RER	RER Limit
Radium-226			11.4	9.274		0.972	1.00	0.0830	pCi/L	82	75 - 125	0.31	1

Carrier	*LCSD %Yield*	*LCSD Qualifier*	*Limits*
Ba Carrier	*103*		*40 - 110*

Method: 904.0 - Radium-228 (GFPC)

Lab Sample ID: MB 160-424232/23-A
Matrix: Water
Analysis Batch: 426899

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 424232

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	-0.2294	U	0.220	0.221	1.00	0.425	pCi/L	04/17/19 10:22	05/06/19 15:01	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*104*		*40 - 110*	*04/17/19 10:22*	*05/06/19 15:01*	*1*
Y Carrier	*80.0*		*40 - 110*	*04/17/19 10:22*	*05/06/19 15:01*	*1*

Lab Sample ID: LCS 160-424232/1-A
Matrix: Water
Analysis Batch: 426797

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 424232

Analyte			Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits		
Radium-228			9.23	8.954		1.04	1.00	0.362	pCi/L	97	75 - 125		

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*110*		*40 - 110*
Y Carrier	*72.1*		*40 - 110*

Lab Sample ID: LCSD 160-424232/2-A
Matrix: Water
Analysis Batch: 426797

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 424232

Analyte			Spike Added	LCSD Result	LCSD Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits	RER	RER Limit
Radium-228			9.23	8.545		0.998	1.00	0.349	pCi/L	93	75 - 125	0.20	1

Method: 904.0 - Radium-228 (GFPC) (Continued)

Lab Sample ID: LCSD 160-424232/2-A
Matrix: Water
Analysis Batch: 426797

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 424232

Carrier	*LCSD %Yield*	*LCSD Qualifier*	*Limits*
Ba Carrier	*106*		*40 - 110*
Y Carrier	*78.9*		*40 - 110*

Lab Sample ID: MB 160-424953/23-A
Matrix: Water
Analysis Batch: 427793

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 424953

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.3031	U	0.205	0.207	1.00	0.317	pCi/L	04/22/19 12:52	05/09/19 08:49	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*109*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*
Y Carrier	*86.4*		*40 - 110*	*04/22/19 12:52*	*05/09/19 08:49*	*1*

Lab Sample ID: LCS 160-424953/1-A
Matrix: Water
Analysis Batch: 427795

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 424953

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-228	9.23	8.758		1.00	1.00	0.374	pCi/L	95	75 - 125

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*101*		*40 - 110*
Y Carrier	*97.6*		*40 - 110*

Lab Sample ID: LCSD 160-424953/2-A
Matrix: Water
Analysis Batch: 427795

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 424953

Analyte	Spike Added	LCSD Result	LCSD Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits	RER	RER Limit
Radium-228	9.23	9.013		1.02	1.00	0.345	pCi/L	98	75 - 125	0.13	1

Carrier	*LCSD %Yield*	*LCSD Qualifier*	*Limits*
Ba Carrier	*103*		*40 - 110*
Y Carrier	*92.3*		*40 - 110*

QC Association Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Rad

Prep Batch: 424079

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-1	MW 301	Total/NA	Ground Water	PrecSep-21	
310-152684-2	MW 302	Total/NA	Ground Water	PrecSep-21	
310-152684-3	MW 303	Total/NA	Ground Water	PrecSep-21	
310-152684-4	MW 304	Total/NA	Ground Water	PrecSep-21	
310-152684-5	MW 305	Total/NA	Ground Water	PrecSep-21	
310-152684-6	MW 306	Total/NA	Ground Water	PrecSep-21	
MB 160-424079/23-A	Method Blank	Total/NA	Water	PrecSep-21	
LCS 160-424079/1-A	Lab Control Sample	Total/NA	Water	PrecSep-21	
LCSD 160-424079/2-A	Lab Control Sample Dup	Total/NA	Water	PrecSep-21	

Prep Batch: 424232

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-1	MW 301	Total/NA	Ground Water	PrecSep_0	
310-152684-2	MW 302	Total/NA	Ground Water	PrecSep_0	
310-152684-3	MW 303	Total/NA	Ground Water	PrecSep_0	
310-152684-4	MW 304	Total/NA	Ground Water	PrecSep_0	
310-152684-5	MW 305	Total/NA	Ground Water	PrecSep_0	
310-152684-6	MW 306	Total/NA	Ground Water	PrecSep_0	
MB 160-424232/23-A	Method Blank	Total/NA	Water	PrecSep_0	
LCS 160-424232/1-A	Lab Control Sample	Total/NA	Water	PrecSep_0	
LCSD 160-424232/2-A	Lab Control Sample Dup	Total/NA	Water	PrecSep_0	

Prep Batch: 424949

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-7	MW 307	Total/NA	Ground Water	PrecSep-21	
310-152684-8	MW 308	Total/NA	Ground Water	PrecSep-21	
310-152684-9	MW 309	Total/NA	Ground Water	PrecSep-21	
310-152684-10	MW 310	Total/NA	Ground Water	PrecSep-21	
310-152684-11	MW 311	Total/NA	Ground Water	PrecSep-21	
310-152684-12	Field Blank	Total/NA	Ground Water	PrecSep-21	
MB 160-424949/23-A	Method Blank	Total/NA	Water	PrecSep-21	
LCS 160-424949/1-A	Lab Control Sample	Total/NA	Water	PrecSep-21	
LCSD 160-424949/2-A	Lab Control Sample Dup	Total/NA	Water	PrecSep-21	

Prep Batch: 424953

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-152684-7	MW 307	Total/NA	Ground Water	PrecSep_0	
310-152684-8	MW 308	Total/NA	Ground Water	PrecSep_0	
310-152684-9	MW 309	Total/NA	Ground Water	PrecSep_0	
310-152684-10	MW 310	Total/NA	Ground Water	PrecSep_0	
310-152684-11	MW 311	Total/NA	Ground Water	PrecSep_0	
310-152684-12	Field Blank	Total/NA	Ground Water	PrecSep_0	
MB 160-424953/23-A	Method Blank	Total/NA	Water	PrecSep_0	
LCS 160-424953/1-A	Lab Control Sample	Total/NA	Water	PrecSep_0	
LCSD 160-424953/2-A	Lab Control Sample Dup	Total/NA	Water	PrecSep_0	

Lab Chronicle

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 301

Lab Sample ID: 310-152684-1

Date Collected: 04/03/19 14:20
Date Received: 04/04/19 18:00
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424079	04/16/19 17:52	CMM	TAL SL
Total/NA	Analysis	903.0		1	428065	05/13/19 06:37	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424232	04/17/19 10:22	HET	TAL SL
Total/NA	Analysis	904.0		1	426797	05/06/19 14:59	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Client Sample ID: MW 302

Lab Sample ID: 310-152684-2

Date Collected: 04/03/19 15:22
Date Received: 04/04/19 18:00
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424079	04/16/19 17:52	CMM	TAL SL
Total/NA	Analysis	903.0		1	428065	05/13/19 06:37	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424232	04/17/19 10:22	HET	TAL SL
Total/NA	Analysis	904.0		1	426797	05/06/19 14:59	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Client Sample ID: MW 303

Lab Sample ID: 310-152684-3

Date Collected: 04/03/19 16:02
Date Received: 04/04/19 18:00
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424079	04/16/19 17:52	CMM	TAL SL
Total/NA	Analysis	903.0		1	428065	05/13/19 06:37	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424232	04/17/19 10:22	HET	TAL SL
Total/NA	Analysis	904.0		1	426797	05/06/19 14:59	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Client Sample ID: MW 304

Lab Sample ID: 310-152684-4

Date Collected: 04/03/19 17:00
Date Received: 04/04/19 18:00
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424079	04/16/19 17:52	CMM	TAL SL
Total/NA	Analysis	903.0		1	428065	05/13/19 06:37	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424232	04/17/19 10:22	HET	TAL SL
Total/NA	Analysis	904.0		1	426797	05/06/19 14:59	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Lab Chronicle

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 305
Date Collected: 04/03/19 13:16
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-5
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424079	04/16/19 17:52	CMM	TAL SL
Total/NA	Analysis	903.0		1	428065	05/13/19 06:37	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424232	04/17/19 10:22	HET	TAL SL
Total/NA	Analysis	904.0		1	426797	05/06/19 14:59	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Client Sample ID: MW 306
Date Collected: 04/03/19 11:22
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-6
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424079	04/16/19 17:52	CMM	TAL SL
Total/NA	Analysis	903.0		1	428063	05/13/19 06:38	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424232	04/17/19 10:22	HET	TAL SL
Total/NA	Analysis	904.0		1	426896	05/06/19 14:57	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Client Sample ID: MW 307
Date Collected: 04/03/19 12:05
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-7
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424949	04/22/19 12:18	JLC	TAL SL
Total/NA	Analysis	903.0		1	429045	05/18/19 21:51	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424953	04/22/19 12:52	JLC	TAL SL
Total/NA	Analysis	904.0		1	427793	05/09/19 08:49	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Client Sample ID: MW 308
Date Collected: 04/03/19 10:33
Date Received: 04/04/19 18:00

Lab Sample ID: 310-152684-8
Matrix: Ground Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424949	04/22/19 12:18	JLC	TAL SL
Total/NA	Analysis	903.0		1	429045	05/18/19 21:51	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424953	04/22/19 12:52	JLC	TAL SL
Total/NA	Analysis	904.0		1	427793	05/09/19 08:49	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Lab Chronicle

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Client Sample ID: MW 309
Lab Sample ID: 310-152684-9
Date Collected: 04/04/19 10:33
Matrix: Ground Water
Date Received: 04/04/19 18:00

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424949	04/22/19 12:18	JLC	TAL SL
Total/NA	Analysis	903.0		1	429045	05/18/19 21:52	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424953	04/22/19 12:52	JLC	TAL SL
Total/NA	Analysis	904.0		1	427793	05/09/19 08:49	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Client Sample ID: MW 310
Lab Sample ID: 310-152684-10
Date Collected: 04/04/19 08:50
Matrix: Ground Water
Date Received: 04/04/19 18:00

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424949	04/22/19 12:18	JLC	TAL SL
Total/NA	Analysis	903.0		1	429045	05/18/19 21:52	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424953	04/22/19 12:52	JLC	TAL SL
Total/NA	Analysis	904.0		1	427793	05/09/19 08:49	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Client Sample ID: MW 311
Lab Sample ID: 310-152684-11
Date Collected: 04/04/19 09:34
Matrix: Ground Water
Date Received: 04/04/19 18:00

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424949	04/22/19 12:18	JLC	TAL SL
Total/NA	Analysis	903.0		1	429045	05/18/19 21:52	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424953	04/22/19 12:52	JLC	TAL SL
Total/NA	Analysis	904.0		1	427793	05/09/19 08:49	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Client Sample ID: Field Blank
Lab Sample ID: 310-152684-12
Date Collected: 04/03/19 13:25
Matrix: Ground Water
Date Received: 04/04/19 18:00

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			424949	04/22/19 12:18	JLC	TAL SL
Total/NA	Analysis	903.0		1	429045	05/18/19 21:52	CDR	TAL SL
Total/NA	Prep	PrecSep_0			424953	04/22/19 12:52	JLC	TAL SL
Total/NA	Analysis	904.0		1	427793	05/09/19 08:49	CDR	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	430228	05/30/19 09:32	SMP	TAL SL

Laboratory References:
TAL SL = Eurofins TestAmerica, St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Accreditation/Certification Summary

Laboratory: Eurofins TestAmerica, Cedar Falls

All accreditations/certifications held by this laboratory are listed. Not all accreditations/certifications are applicable to this report.

Authority	Program	EPA Region	Identification Number	Expiration Date
AIHA-LAP, LLC	IHLAP		101044	11-01-20
Georgia	State Program	4	IA100001 (OR)	09-29-19
Illinois	NELAP	5	200024	11-29-19
Illinois	NELAP		200024	11-29-19
Iowa	State Program	7	007	12-01-19
Kansas	NELAP	7	E-10341	01-31-20
Minnesota	NELAP	5	019-999-319	12-31-19
Minnesota	NELAP		019-999-319	12-31-19
Minnesota (Petrofund)	State Program	1	3349	08-22-19
North Dakota	State Program	8	R-186	09-29-19
Oregon	NELAP	10	IA100001	09-29-19
Oregon	NELAP		IA100001	09-29-19
USDA	Federal		P330-19-00003	01-02-22

Laboratory: Eurofins TestAmerica, St. Louis

The accreditations/certifications listed below are applicable to this report.

Authority	Program	EPA Region	Identification Number	Expiration Date
Iowa	State Program	7	373	12-01-20

Method Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Method	Method Description	Protocol	Laboratory
903.0	Radium-226 (GFPC)	EPA	TAL SL
904.0	Radium-228 (GFPC)	EPA	TAL SL
Ra226_Ra228 Pos	Combined Radium-226 and Radium-228	TAL-STL	TAL SL
PrecSep_0	Preparation, Precipitate Separation	None	TAL SL
PrecSep-21	Preparation, Precipitate Separation (21-Day In-Growth)	None	TAL SL

Protocol References:

EPA = US Environmental Protection Agency

None = None

TAL-STL = TestAmerica Laboratories, St. Louis, Facility Standard Operating Procedure.

Laboratory References:

TAL SL = Eurofins TestAmerica, St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Table 1. Sampling Points and Parameters - CCR Rule Sampling Program
Groundwater Monitoring - Burlington Generating Station / SCS Engineers Project #25215173.10, Task 2

	Parameter	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306	MW-307	MW-308	MW-309	MW-310	MW-311	Field Blank	TOTAL
Appendix III Parameters	Boron	x	x	x	x	x	x	x	x	x	x	x	x	12
	Calcium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Chloride	x	x	x	x	x	x	x	x	x	x	x	x	12
	Fluoride	x	x	x	x	x	x	x	x	x	x	x	x	12
	pH	x	x	x	x	x	x	x	x	x	x	x	x	12
	Sulfate	x	x	x	x	x	x	x	x	x	x	x	x	12
	TDS	x	x	x	x	x	x	x	x	x	x	x	x	12
Appendix IV Parameters	Antimony	x	x	x	x	x	x	x	x	x	x	x	x	12
	Arsenic	x	x	x	x	x	x	x	x	x	x	x	x	12
	Barium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Beryllium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Cadmium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Chromium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Cobalt	x	x	x	x	x	x	x	x	x	x	x	x	12
	Fluoride	x	x	x	x	x	x	x	x	x	x	x	x	12
	Lead	x	x	x	x	x	x	x	x	x	x	x	x	12
	Lithium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Mercury	x	x	x	x	x	x	x	x	x	x	x	x	12
	Molybdenum	x	x	x	x	x	x	x	x	x	x	x	x	12
	Selenium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Thallium	x	x	x	x	x	x	x	x	x	x	x	x	12
	Radium	x	x	x	x	x	x	x	x	x	x	x	x	12
Field Parameters	Groundwater Elevation	x	x	x	x	x	x	x	x	x	x	x		11
	Well Depth	x	x	x	x	x	x	x	x	x	x	x		11
	pH (field)	x	x	x	x	x	x	x	x	x	x	x		11
	Specific Conductance	x	x	x	x	x	x	x	x	x	x	x		11
	Dissolved Oxygen	x	x	x	x	x	x	x	x	x	x	x		11
	ORP	x	x	x	x	x	x	x	x	x	x	x		11
	Temperature	x	x	x	x	x	x	x	x	x	x	x		11
	Turbidity	x	x	x	x	x	x	x	x	x	x	x		11
	Color	x	x	x	x	x	x	x	x	x	x	x		11
	Odor	x	x	x	x	x	x	x	x	x	x	x		11

Notes: All samples are unfiltered (total).

C:\Users\3510med\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Outlook\1WB99N1Q\[Table_

TestAmerica
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310-152684 Chain of Custody

Cooler/Sample Receipt and Temperature Log Form

Client Information			
Client:	SCS Engineers		
City/State:	CITY Clive / STATE IA	Project:	Burlington
Receipt Information			
Date/Time Received:	DATE 4-4-19 / TIME 1800	Received By:	LAB

Delivery Type: ☐ UPS ☐ FedEx ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee ☒ Lab Courier ☐ TA Field Services ☐ Client Drop-off ☐ Other:________

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes	☐ No	*If yes:* Cooler ID:	EZ8
Multiple Coolers?	☒ Yes	☐ No	*If yes:* Cooler #	1 of 3
Cooler Custody Seals Present?	☒ Yes	☐ No	*If yes:* Cooler custody seals intact?	☒ Yes ☐ No
Sample Custody Seals Present?	☐ Yes	☒ No	*If yes:* Sample custody seals intact?	☐ Yes ☐ No
Trip Blank Present?	☐ Yes	☒ No	*If yes:* Which VOA samples are in cooler? ↓	

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:________ ☐ NONE

Thermometer ID:	N	Correction Factor (°C):	+0.0

• **Temp Blank Temperature** – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C):	1.7	Corrected Temp (°C):	1.7

• **Sample Container Temperature**

Container type(s) used:	CONTAINER 1	CONTAINER 2
Uncorrected Temp (°C):	TEMP 1	TEMP 2
Corrected Temp (°C):	TEMP 1	TEMP 2

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

Document: CF-LG-WI-002
Revision: 24
Date: 03/07/2019

General temperature criteria is 0 to 6°C
Bacteria temperature criteria is 0 to 10°C

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Place COC scanning label here
214

Cooler/Sample Receipt and Temperature Log Form

Client Information

Client: SCS Engineers

City/State: CITY Clive STATE IA | Project: Burlington

Receipt Information

Date/Time Received: DATE 4-4-19 TIME 1800 | Received By: LAB

Delivery Type: ☐ UPS ☐ FedEx ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee
☒ Lab Courier ☐ TA Field Services ☐ Client Drop-off ☐ Other:____________

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes ☐ No	*If yes:* Cooler ID:	
Multiple Coolers?	☒ Yes ☐ No	*If yes:* Cooler # 2 of 3	
Cooler Custody Seals Present?	☒ Yes ☐ No	*If yes:* Cooler custody seals intact?	☒ Yes ☐ No
Sample Custody Seals Present?	☐ Yes ☒ No	*If yes:* Sample custody seals intact?	☐ Yes ☐ No
Trip Blank Present?	☐ Yes ☒ No	*If yes:* Which VOA samples are in cooler? ↓	

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:__________ ☐ NONE

Thermometer ID: N | Correction Factor (°C): +0.0

• **Temp Blank Temperature** – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): 3.8 | Corrected Temp (°C): 3.8

• **Sample Container Temperature**

Container type(s) used: CONTAINER 1 | CONTAINER 2

Uncorrected Temp (°C): TEMP 1 | TEMP 2 | Corrected Temp (°C): TEMP 1 | TEMP 2

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

Document: CF-LG-WI-002
Revision: 24
Date: 03/07/2019

General temperature criteria is 0 to 6°C
Ice/refrigeration temperature criteria is 0 to 10°C

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

Place COC scanning label here
214

Cooler/Sample Receipt and Temperature Log Form

Client Information

Client: SCS Engineers			
City/State: CITY Olive	STATE IA	Project: Burlington	

Receipt Information

Date/Time Received: DATE 4-4-19	TIME 1800	Received By: LAB	

Delivery Type: ☐ UPS ☐ FedEx ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee
☒ Lab Courier ☐ TA Field Services ☐ Client Drop-off ☐ Other:__________

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes	☐ No	*If yes:* Cooler ID: AA-18
Multiple Coolers?	☒ Yes	☐ No	*If yes:* Cooler # 3 of 3
Cooler Custody Seals Present?	☒ Yes	☐ No	*If yes:* Cooler custody seals intact? ☒ Yes ☐ No
Sample Custody Seals Present?	☐ Yes	☒ No	*If yes:* Sample custody seals intact? ☐ Yes ☐ No
Trip Blank Present?	☐ Yes	☒ No	*If yes:* Which VOA samples are in cooler? ↓

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:________ ☐ NONE

Thermometer ID: N	Correction Factor (°C): +0.0

• **Temp Blank Temperature** – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): 4.2	Corrected Temp (°C): 4.2

• **Sample Container Temperature**

Container type(s) used:	CONTAINER 1		CONTAINER 2	
Uncorrected Temp (°C):	TEMP 1	TEMP 2	Corrected Temp (°C): TEMP 1	TEMP 2

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

2 1L Nitric, 1 PL 250 Nitric + 1 PL 500 NT rcvd empty

Document: CF-LG-WI-002
Revision: 24
Date: 03/07/2019

General temperature criteria is 0 to 6°C
Bacteria temperature criteria is 0 to 10°C

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING
Cedar Falls Division
704 Enterprise Drive
Cedar Falls, IA 50613
Phone 319-277-2401 or 800-750-2401
Fax 319-277-2425

TestAmerica Des Moines SC
214

To assist us in using the proper analytical methods, is this work being conducted for regulatory purposes?
Compliance Monitoring ______

Client Name: SCS Engineers Client #:
Address: 8450 Hickman Rd Suite 20
City/State/Zip Code: Clive IA
Project Manager:
Email Address:
Telephone Number: Fax:
Sampler Name: (Print Name) Nick Schemmel
Sampler Signature: [signature]

Project Name: Burlington
Project #: 25216066
Site/Location ID: Burlington State: IA
Report To:
Invoice To:
Quote #: PO#:

TAT
___ Standard
___ Rush (surcharges may apply)

Date Needed: ______

Fax Results: Y N
Email Results: Y N

QC Deliverables
___ None
___ Level 2 *(Batch QC)*
___ Level 3
___ Level 4
Other: ______

SAMPLE ID	Date Sampled	Time Sampled	G = Grab, C = Composite	Field Filtered	Matrix (SL - Sludge, DW - Drinking Water, S - Soil/Solid, GW - Groundwater, WW - Wastewater, Specify, Other)	HNO_3	HCl	NaOH	H_2SO_4	Methanol	None	Other (Specify)	Metals	pH	TDS	Chloride/Fluoride/SO4	Radium 226+228						REMARKS
MW 301	4.3.19	1420	G		GW	3					1		✓	X	X	X	X						
MW 302	↓	1522	↓		↓	3					1		X	X	X	X	X						
MW 303	↓	1602	↓		↓	3					1		X	X	X	X	X						
MW 304	↓	1700	↓		↓	3					1		X	X	X	X	X						
MW 305	↓	1316	↓		↓	3					1		X	X	X	X	X						
MW 306	↓	1122	↓		↓	3					1		X	X	X	X	X						
MW 307	↓	1205	↓		↓	3					1		X	X	X	X	X						
MW 308	↓	1033	↓		↓	3					1		X	X	X	X	X						
MW 309	4.4.19	1033	↓		↓	3					1		X	X	X	X	X						

Special Instructions:

LABORATORY COMMENTS:

Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Nick Schemmel	4.4.19		[signature]	4.4.19	14:59
			Lindsay Bardell	4.4.19	1800
	~~4.4.19~~				

TAL-0033 (0708)

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Cedar Falls Division
704 Enterprise Drive
Cedar Falls, IA 50613

Phone 319-277-2401 or 800-750-2401
Fax 319-277-2425

To assist us in using the proper analytical methods, is this work being conducted for regulatory purposes?
Compliance Monitoring ______

TestAmerica Des Moines SC
214

Client Name: SCS Engineers   Client #: ______
Address: 8450 Hickman Rd Suite 20
City/State/Zip Code: Clive IA
Project Manager: ______
Email Address: ______
Telephone Number: ______   Fax: ______
Sampler Name: (Print Name) Nick Schemmel
Sampler Signature: [signature]

Project Name: Burlington
Project #: 25216066
Site/Location ID: Burlington   State: IA
Report To: ______
Invoice To: ______
Quote #: ______   PO#: ______

TAT
___ Standard
___ Rush (surcharges may apply)

Date Needed: ______

Fax Results: Y N
Email Results: Y N

QC Deliverables
___ None
___ Level 2
(Batch QC)
___ Level 3
___ Level 4
Other: ______

SAMPLE ID	Date Sampled	Time Sampled	G = Grab, C = Composite	Field Filtered	Matrix: SL - Sludge, DW - Drinking Water, GW - Groundwater, S - Soil/Solid, WW - Wastewater, Specify, Other	Preservation & # of Containers: HNO_3	HCl	NaOH	H_2SO_4	Methanol	None	Other (Specify)	Analyze For: Metals	pH	TDS	Chloride/Fluoride/SO4	Radium 226+228						REMARKS
MW 310	4.4.19	0850	G		GW	3					1		X	X	X	X	X						
MW 311	↓	0934	↓		↓	3					1		X	X	X	X	X						
Field Blank	4.3.19	1325	↓		↓	3					1		X	X	X	X	X						

Special Instructions:

LABORATORY COMMENTS:

Relinquished By	Date	Time	Received By	Date	Time
Nick Schemmel	4.4.19		[signature]	4/4/19	14:59
			Lindsay Brodt	4 4 19	1800

TAL-0033 (0708)

Page ______ of ______

Login Container Summary Report

Temperature readings: ______________________________

Client Sample ID	Lab ID	Container Type	Container pH	Preservative Added (mls)	Lot #
MW 301	310-152684-A-1	Plastic 250ml - with Nitric Acid	<2		
MW 301	310-152684-C-1	Plastic 1 liter - Nitric Acid	<2		
MW 301	310-152684-D-1	Plastic 1 liter - Nitric Acid	<2		
MW 302	310-152684-A-2	Plastic 250ml - with Nitric Acid	<2		
MW 302	310-152684-C-2	Plastic 1 liter - Nitric Acid	<2		
MW 302	310-152684-D-2	Plastic 1 liter - Nitric Acid	<2		
MW 303	310-152684-A-3	Plastic 250ml - with Nitric Acid	<2		
MW 303	310-152684-C-3	Plastic 1 liter - Nitric Acid	<2		
MW 303	310-152684-D-3	Plastic 1 liter - Nitric Acid	<2		
MW 304	310-152684-A-4	Plastic 250ml - with Nitric Acid	<2		
MW 304	310-152684-C-4	Plastic 1 liter - Nitric Acid	<2		
MW 304	310-152684-D-4	Plastic 1 liter - Nitric Acid	<2		
MW 305	310-152684-A-5	Plastic 250ml - with Nitric Acid	<2		
MW 305	310-152684-C-5	Plastic 1 liter - Nitric Acid	<2		
MW 305	310-152684-D-5	Plastic 1 liter - Nitric Acid	<2		
MW 306	310-152684-A-6	Plastic 250ml - with Nitric Acid	<2		
MW 306	310-152684-C-6	Plastic 1 liter - Nitric Acid	<2		
MW 306	310-152684-D-6	Plastic 1 liter - Nitric Acid	<2		
MW 307	310-152684-A-7	Plastic 250ml - with Nitric Acid	<2		
MW 307	310-152684-C-7	Plastic 1 liter - Nitric Acid	<2		
MW 307	310-152684-D-7	Plastic 1 liter - Nitric Acid	<2		
MW 308	310-152684-A-8	Plastic 250ml - with Nitric Acid	<2		
MW 308	310-152684-C-8	Plastic 1 liter - Nitric Acid	<2		
MW 308	310-152684-D-8	Plastic 1 liter - Nitric Acid	<2		
MW 309	310-152684-A-9	Plastic 250ml - with Nitric Acid	<2		
MW 309	310-152684-C-9	Plastic 1 liter - Nitric Acid	<2		
MW 309	310-152684-D-9	Plastic 1 liter - Nitric Acid	<2		
MW 310	310-152684-A-10	Plastic 250ml - with Nitric Acid	<2		
MW 310	310-152684-C-10	Plastic 1 liter - Nitric Acid	<2		
MW 310	310-152684-D-10	Plastic 1 liter - Nitric Acid	<2		
MW 311	310-152684-A-11	Plastic 250ml - with Nitric Acid	<2		
MW 311	310-152684-C-11	Plastic 1 liter - Nitric Acid	<2		
MW 311	310-152684-D-11	Plastic 1 liter - Nitric Acid	<2		
Field Blank	310-152684-A-12	Plastic 250ml - with Nitric Acid	<2		
Field Blank	310-152684-C-12	Plastic 1 liter - Nitric Acid	<2		
Field Blank	310-152684-D-12	Plastic 1 liter - Nitric Acid	<2		

Client Sample ID	Lab ID	Container Type	Container pH	Preservative Added (mls)	Lot #

Page 2 of 2

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Eurofins TestAmerica, Cedar Falls
704 Enterprise Drive
Cedar Falls, IA 50613
Phone (319) 277-2401 Fax (319) 277-2425

Chain of Custody Record

eurofins

Client Information (Sub Contract Lab)	Sampler:	Lab PM: Fredrick, Sandie	Carrier Tracking No(s):	COC No: 310-16049.2
Client Contact: Shipping/Receiving	Phone:	E-Mail: sandie.fredrick@testamericainc.com	State of Origin: Iowa	Page: Page 2 of 2
Company: TestAmerica Laboratories, Inc.		Accreditations Required (See note): IA Rad Material License - Iowa; State Program - Iowa		Job #: 310-152684-2
Address: 13715 Rider Trail North,	Due Date Requested: 5/2/2019	Analysis Requested		Preservation Codes:
City: Earth City	TAT Requested (days):			
State, Zip: MO, 63045				
Phone: 314-298-8566(Tel) 314-298-8757(Fax)	PO #:			
Email:	WO #:			
Project Name: Burlington - 25216066	Project #: 31011020			
Site:	SSOW#:			

Preservation Codes: A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA, M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)

Other:

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	903.0/PrecSep_21 Standard Target List	904.0/PrecSep_0 Standard Target List	Ra226_228GFPC_P	Total Number of containers	Special Instructions/Note:
			Preservation Code:								
MW 310 (310-152684-10)	4/4/19	08:50 Central		Water			X	X	X	2	
MW 311 (310-152684-11)	4/4/19	09:34 Central		Water			X	X	X	2	
Field Blank (310-152684-12)	4/3/19	13:25 Central		Water			X	X	X	2	

310-152684 Chain of Custody

Note: Since laboratory accreditations are subject to change, TestAmerica Laboratories, Inc. places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. I

Possible Hazard Identification

Unconfirmed

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* ______ *Months*

Deliverable Requested: I, II, III, IV, Other (specify) — Primary Deliverable Rank: 2

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:		
Relinquished by: [signature]	Date/Time: 4/5/19 1631	Company	Received by: Michael Flum	Date/Time: 4-6-19 08:30	Company: TA STL
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:		Cooler Temperature(s) °C and Other Remarks:		

Ver: 01/16/2019

Eurofins TestAmerica, Cedar Falls
704 Enterprise Drive
Cedar Falls, IA 50613
Phone (319) 277-2401 Fax (319) 277-2425

Chain of Custody Record

eurofins

Client Information (Sub Contract Lab)	Sampler:	Lab PM: Fredrick, Sandie	Carrier Tracking No(s):	COC No: 310-16049.1
Client Contact: Shipping/Receiving	Phone:	E-Mail: sandie.fredrick@testamericainc.com	State of Origin: Iowa	Page: Page 1 of 2
Company: TestAmerica Laboratories, Inc.		Accreditations Required (See note): IA Rad Material License - Iowa, State Program - Iowa		Job #: 310-152684-2
Address: 13715 Rider Trail North,	Due Date Requested: 5/2/2019	**Analysis Requested**		**Preservation Codes:**
City: Earth City	TAT Requested (days):			A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA; M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
State, Zip: MO, 63045				
Phone: 314-298-8566(Tel) 314-298-8757(Fax)	PO #:			
Email:	WO #:			Other:
Project Name: Burlington - 25216066	Project #: 31011020			
Site:	SSOW#:			

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	903.0/PrecSep_21 Standard Target List	904.0/PrecSep_0 Standard Target List	Ra226_228GFPC_P	Total Number of containers	Special Instructions/Note:
			Preservation Code:								
MW 301 (310-152684-1)	4/3/19	14:20 Central		Water			X	X	X	2	
MW 302 (310-152684-2)	4/3/19	15:22 Central		Water			X	X	X	2	
MW 303 (310-152684-3)	4/3/19	16:02 Central		Water			X	X	X	2	
MW 304 (310-152684-4)	4/3/19	17:00 Central		Water			X	X	X	2	
MW 305 (310-152684-5)	4/3/19	13:16 Central		Water			X	X	X	2	
MW 306 (310-152684-6)	4/3/19	11:22 Central		Water			X	X	X	2	
MW 307 (310-152684-7)	4/3/19	12:05 Central		Water			X	X	X	2	
MW 308 (310-152684-8)	4/3/19	10:33 Central		Water			X	X	X	2	
MW 309 (310-152684-9)	4/4/19	10:33 Central		Water			X	X	X	2	

Note: Since laboratory accreditations are subject to change, TestAmerica Laboratories, Inc. places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. If the laboratory does not currently maintain accreditation in the State of Origin listed above for analysis/tests/matrix being analyzed, the samples must be shipped back to the TestAmerica laboratory or other instructions will be provided. Any changes to accreditation status should be brought to TestAmerica Laboratories, Inc. attention immediately. If all requested accreditations are current to date, return the signed Chain of Custody attesting to said complicance to TestAmerica Laboratories, Inc.

Possible Hazard Identification *Unconfirmed*		*Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)* ☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* ____ *Months*
Deliverable Requested: I, II, III, IV, Other (specify)	Primary Deliverable Rank: 2	Special Instructions/QC Requirements:
Empty Kit Relinquished by:	Date:	Time: / Method of Shipment:

Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
[signature]	4/5/19 1630		Michael Heun	4-6-19 08:20	TA SL
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company

Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:	Cooler Temperature(s) °C and Other Remarks:

Ver: 01/16/2019

Login Sample Receipt Checklist

Client: SCS Engineers

Job Number: 310-152684-2
SDG Number: 25216066

Login Number: 152684
List Number: 1
Creator: Bovy, Lorrainna L

List Source: Eurofins TestAmerica, Cedar Falls

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Login Sample Receipt Checklist

Client: SCS Engineers

Job Number: 310-152684-2
SDG Number: 25216066

Login Number: 152684
List Number: 2
Creator: Hellm, Michael

List Source: Eurofins TestAmerica, St. Louis
List Creation: 04/08/19 06:33 AM

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	N/A	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	18.0
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	N/A	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	N/A	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Tracer/Carrier Summary

Client: SCS Engineers
Project/Site: Burlington - 25216066

Job ID: 310-152684-2
SDG: 25216066

Method: 903.0 - Radium-226 (GFPC)

Matrix: Ground Water **Prep Type: Total/NA**

Percent Yield (Acceptance Limits)

Lab Sample ID	Client Sample ID	Ba Carrier (40-110)
310-152684-1	MW 301	101
310-152684-2	MW 302	93.8
310-152684-3	MW 303	100
310-152684-4	MW 304	97.5
310-152684-5	MW 305	91.0
310-152684-6	MW 306	99.2
310-152684-7	MW 307	94.9
310-152684-8	MW 308	98.9
310-152684-9	MW 309	98.6
310-152684-10	MW 310	100
310-152684-11	MW 311	100
310-152684-12	Field Blank	93.8

Tracer/Carrier Legend

Ba Carrier = Ba Carrier

Method: 903.0 - Radium-226 (GFPC)

Matrix: Water **Prep Type: Total/NA**

Percent Yield (Acceptance Limits)

Lab Sample ID	Client Sample ID	Ba Carrier (40-110)
LCS 160-424079/1-A	Lab Control Sample	110
LCS 160-424949/1-A	Lab Control Sample	101
LCSD 160-424079/2-A	Lab Control Sample Dup	106
LCSD 160-424949/2-A	Lab Control Sample Dup	103
MB 160-424079/23-A	Method Blank	104
MB 160-424949/23-A	Method Blank	109

Tracer/Carrier Legend

Ba Carrier = Ba Carrier

Method: 904.0 - Radium-228 (GFPC)

Matrix: Ground Water **Prep Type: Total/NA**

Percent Yield (Acceptance Limits)

Lab Sample ID	Client Sample ID	Ba Carrier (40-110)	Y Carrier (40-110)
310-152684-1	MW 301	101	80.0
310-152684-2	MW 302	93.8	80.4
310-152684-3	MW 303	100	73.3
310-152684-4	MW 304	97.5	76.6
310-152684-5	MW 305	91.0	75.1
310-152684-6	MW 306	99.2	79.3
310-152684-7	MW 307	94.9	90.8
310-152684-8	MW 308	98.9	92.3
310-152684-9	MW 309	98.6	88.6
310-152684-10	MW 310	100	90.8
310-152684-11	MW 311	100	91.2
310-152684-12	Field Blank	93.8	93.5

Tracer/Carrier Legend

Tracer/Carrier Summary

Client: SCS Engineers | Job ID: 310-152684-2
Project/Site: Burlington - 25216066 | SDG: 25216066

Ba Carrier = Ba Carrier
Y Carrier = Y Carrier

Method: 904.0 - Radium-228 (GFPC)

Matrix: Water | **Prep Type: Total/NA**

		Percent Yield (Acceptance Limits)	
Lab Sample ID	**Client Sample ID**	**Ba Carrier (40-110)**	**Y Carrier (40-110)**
LCS 160-424232/1-A	Lab Control Sample	110	72.1
LCS 160-424953/1-A	Lab Control Sample	101	97.6
LCSD 160-424232/2-A	Lab Control Sample Dup	106	78.9
LCSD 160-424953/2-A	Lab Control Sample Dup	103	92.3
MB 160-424232/23-A	Method Blank	104	80.0
MB 160-424953/23-A	Method Blank	109	86.4

Tracer/Carrier Legend

Ba Carrier = Ba Carrier
Y Carrier = Y Carrier

A2 Assessment Monitoring – Newly Installed Monitoring Wells, June 2019

eurofins | Environment Testing
TestAmerica

ANALYTICAL REPORT

Eurofins TestAmerica, Cedar Falls
3019 Venture Way
Cedar Falls, IA 50613
Tel: (319)277-2401

Laboratory Job ID: 310-157442-1
Client Project/Site: Alliant Burlington 25218220
Revision: 1

For:
SCS Engineers
2830 Dairy Drive
Madison, Wisconsin 53718

Attn: Meghan Blodgett

Authorized for release by:
7/12/2019 4:14:16 PM

Sandie Fredrick, Project Manager II
(920)261-1660
sandie.fredrick@testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Case Narrative

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

Job ID: 310-157442-1

Laboratory: Eurofins TestAmerica, Cedar Falls

Narrative

Job Narrative
310-157442-1

Comments
FIELD BLANK WATER DATA REVIEW: **After review by the lab, the field blank water supplied for this analysis had notable concentrations of chloride, fluoride, sulfate, TDS, Barium, Calcium and Molydenum present. Reanalysis of the remaining service center field blank water confirms the higher levels of analytes present.**

Receipt
The samples were received on 6/7/2019 10:00 AM; the samples arrived in good condition, properly preserved and, where required, on ice. The temperature of the cooler at receipt was 3.8º C.

HPLC/IC
Method(s) 9056A: The following sample was diluted due to the nature of the sample matrix: MW313 (310-157442-3). Elevated reporting limits (RLs) are provided.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

Metals
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

General Chemistry
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Sample Summary

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received	Asset ID
310-157442-1	Field Blank	Water	06/06/19 08:30	06/07/19 10:00	
310-157442-2	MW-312	Water	06/06/19 09:00	06/07/19 10:00	
310-157442-3	MW-313	Water	06/06/19 11:30	06/07/19 10:00	

Detection Summary

Client: SCS Engineers
Job ID: 310-157442-1
Project/Site: Alliant Burlington 25218220

Client Sample ID: Field Blank
Lab Sample ID: 310-157442-1

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	22		1.0	0.29	mg/L	1		9056A	Total/NA
Fluoride	0.84		0.10	0.045	mg/L	1		9056A	Total/NA
Sulfate	38		1.0	0.35	mg/L	1		9056A	Total/NA
Barium	3.3		2.0	0.84	ug/L	1		6020A	Total/NA
Calcium	0.35	J	0.50	0.10	mg/L	1		6020A	Total/NA
Molybdenum	1.2	J	2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	330		30	24	mg/L	1		SM 2540C	Total/NA
pH	7.7	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA

Client Sample ID: MW-312
Lab Sample ID: 310-157442-2

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	27		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	1.1		0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	220		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	14		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	160		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	6100		800	440	ug/L	4		6020A	Total/NA
Calcium	67		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.65		0.50	0.091	ug/L	1		6020A	Total/NA
Lead	0.54		0.50	0.27	ug/L	1		6020A	Total/NA
Lithium	24		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	290		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	540		30	24	mg/L	1		SM 2540C	Total/NA
pH	7.5	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-146.4				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.12				mg/L	1		Field Sampling	Total/NA
pH, Field	6.99				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	783				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	14.4				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	2.86				NTU	1		Field Sampling	Total/NA

Client Sample ID: MW-313
Lab Sample ID: 310-157442-3

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	85		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.33	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	210		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	5.5		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	510		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	7400		800	440	ug/L	4		6020A	Total/NA
Calcium	110		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.41	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lithium	43		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	130		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	700		30	24	mg/L	1		SM 2540C	Total/NA
pH	7.4	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-141.6				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.07				mg/L	1		Field Sampling	Total/NA
pH, Field	6.94				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	1059				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	14.9				Degrees C	1		Field Sampling	Total/NA

This Detection Summary does not include radiochemical test results.

Eurofins TestAmerica, Cedar Falls

Detection Summary

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

Client Sample ID: MW-313 (Continued)

Lab Sample ID: 310-157442-3

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Turbidity, Field	7.23				NTU	1		Field Sampling	Total/NA

This Detection Summary does not include radiochemical test results.

Client Sample Results

Client: SCS Engineers
Job ID: 310-157442-1
Project/Site: Alliant Burlington 25218220

Client Sample ID: Field Blank
Lab Sample ID: 310-157442-1

Date Collected: 06/06/19 08:30
Matrix: Water
Date Received: 06/07/19 10:00

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**22**		1.0	0.29	mg/L			06/10/19 19:18	1
Fluoride	**0.84**		0.10	0.045	mg/L			06/10/19 19:18	1
Sulfate	**38**		1.0	0.35	mg/L			06/10/19 19:18	1

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		06/10/19 07:54	06/10/19 14:22	1
Arsenic	<0.75		2.0	0.75	ug/L		06/10/19 07:54	06/10/19 14:22	1
Barium	**3.3**		2.0	0.84	ug/L		06/10/19 07:54	06/10/19 14:22	1
Beryllium	<0.27		1.0	0.27	ug/L		06/10/19 07:54	06/10/19 14:22	1
Boron	<110		200	110	ug/L		06/10/19 07:54	06/10/19 14:22	1
Cadmium	<0.077		0.50	0.077	ug/L		06/10/19 07:54	06/10/19 14:22	1
Calcium	**0.35**	**J**	0.50	0.10	mg/L		06/10/19 07:54	06/10/19 14:22	1
Chromium	<0.98		5.0	0.98	ug/L		06/10/19 07:54	06/10/19 14:22	1
Cobalt	<0.091		0.50	0.091	ug/L		06/10/19 07:54	06/10/19 14:22	1
Lead	<0.27		0.50	0.27	ug/L		06/10/19 07:54	06/10/19 14:22	1
Lithium	<2.7		10	2.7	ug/L		06/10/19 07:54	06/10/19 14:22	1
Molybdenum	**1.2**	**J**	2.0	1.1	ug/L		06/10/19 07:54	06/10/19 14:22	1
Selenium	<1.0		5.0	1.0	ug/L		06/10/19 07:54	06/10/19 14:22	1
Thallium	<0.27		1.0	0.27	ug/L		06/10/19 07:54	06/10/19 14:22	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		06/10/19 08:32	06/10/19 13:44	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**330**		30	24	mg/L			06/07/19 11:09	1
pH	**7.7**	**HF**	0.1	0.1	SU			06/07/19 21:50	1

Client Sample Results

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

Client Sample ID: MW-312
Date Collected: 06/06/19 09:00
Date Received: 06/07/19 10:00

Lab Sample ID: 310-157442-2
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**27**		5.0	1.5	mg/L			06/10/19 20:05	5
Fluoride	**1.1**		0.50	0.23	mg/L			06/10/19 20:05	5
Sulfate	**220**		5.0	1.8	mg/L			06/10/19 20:05	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		06/10/19 07:54	06/10/19 14:36	1
Arsenic	**14**		2.0	0.75	ug/L		06/10/19 07:54	06/10/19 14:36	1
Barium	**160**		2.0	0.84	ug/L		06/10/19 07:54	06/10/19 14:36	1
Beryllium	<0.27		1.0	0.27	ug/L		06/10/19 07:54	06/10/19 14:36	1
Boron	**6100**		800	440	ug/L		06/10/19 07:54	06/10/19 14:43	4
Cadmium	<0.077		0.50	0.077	ug/L		06/10/19 07:54	06/10/19 14:36	1
Calcium	**67**		0.50	0.10	mg/L		06/10/19 07:54	06/10/19 14:36	1
Chromium	<0.98		5.0	0.98	ug/L		06/10/19 07:54	06/10/19 14:36	1
Cobalt	**0.65**		0.50	0.091	ug/L		06/10/19 07:54	06/10/19 14:36	1
Lead	**0.54**		0.50	0.27	ug/L		06/10/19 07:54	06/10/19 14:36	1
Lithium	**24**		10	2.7	ug/L		06/10/19 07:54	06/10/19 14:36	1
Molybdenum	**290**		2.0	1.1	ug/L		06/10/19 07:54	06/10/19 14:36	1
Selenium	<1.0		5.0	1.0	ug/L		06/10/19 07:54	06/10/19 14:36	1
Thallium	<0.27		1.0	0.27	ug/L		06/10/19 07:54	06/10/19 14:36	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		06/10/19 08:32	06/10/19 13:46	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**540**		30	24	mg/L			06/07/19 11:09	1
pH	**7.5**	**HF**	0.1	0.1	SU			06/07/19 21:54	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-146.4**				millivolts			06/06/19 09:00	1
Oxygen, Dissolved, Client Supplied	**0.12**				mg/L			06/06/19 09:00	1
pH, Field	**6.99**				SU			06/06/19 09:00	1
Specific Conductance, Field	**783**				umhos/cm			06/06/19 09:00	1
Temperature, Field	**14.4**				Degrees C			06/06/19 09:00	1
Turbidity, Field	**2.86**				NTU			06/06/19 09:00	1

Client Sample Results

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

Client Sample ID: MW-313
Date Collected: 06/06/19 11:30
Date Received: 06/07/19 10:00

Lab Sample ID: 310-157442-3
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**85**		5.0	1.5	mg/L			06/10/19 20:20	5
Fluoride	**0.33**	**J**	0.50	0.23	mg/L			06/10/19 20:20	5
Sulfate	**210**		5.0	1.8	mg/L			06/10/19 20:20	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		06/10/19 07:54	06/10/19 14:39	1
Arsenic	**5.5**		2.0	0.75	ug/L		06/10/19 07:54	06/10/19 14:39	1
Barium	**510**		2.0	0.84	ug/L		06/10/19 07:54	06/10/19 14:39	1
Beryllium	<0.27		1.0	0.27	ug/L		06/10/19 07:54	06/10/19 14:39	1
Boron	**7400**		800	440	ug/L		06/10/19 07:54	06/10/19 14:46	4
Cadmium	<0.077		0.50	0.077	ug/L		06/10/19 07:54	06/10/19 14:39	1
Calcium	**110**		0.50	0.10	mg/L		06/10/19 07:54	06/10/19 14:39	1
Chromium	<0.98		5.0	0.98	ug/L		06/10/19 07:54	06/10/19 14:39	1
Cobalt	**0.41**	**J**	0.50	0.091	ug/L		06/10/19 07:54	06/10/19 14:39	1
Lead	<0.27		0.50	0.27	ug/L		06/10/19 07:54	06/10/19 14:39	1
Lithium	**43**		10	2.7	ug/L		06/10/19 07:54	06/10/19 14:39	1
Molybdenum	**130**		2.0	1.1	ug/L		06/10/19 07:54	06/10/19 14:39	1
Selenium	<1.0		5.0	1.0	ug/L		06/10/19 07:54	06/10/19 14:39	1
Thallium	<0.27		1.0	0.27	ug/L		06/10/19 07:54	06/10/19 14:39	1

Method: 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		06/10/19 08:32	06/10/19 13:48	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**700**		30	24	mg/L			06/07/19 11:09	1
pH	**7.4**	**HF**	0.1	0.1	SU			06/07/19 21:58	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-141.6**				millivolts			06/06/19 11:30	1
Oxygen, Dissolved, Client Supplied	**0.07**				mg/L			06/06/19 11:30	1
pH, Field	**6.94**				SU			06/06/19 11:30	1
Specific Conductance, Field	**1059**				umhos/cm			06/06/19 11:30	1
Temperature, Field	**14.9**				Degrees C			06/06/19 11:30	1
Turbidity, Field	**7.23**				NTU			06/06/19 11:30	1

Definitions/Glossary

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

Qualifiers

HPLC/IC

Qualifier	Qualifier Description
J	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

Metals

Qualifier	Qualifier Description
J	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

General Chemistry

Qualifier	Qualifier Description
HF	Field parameter with a holding time of 15 minutes. Test performed by laboratory at client's request.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

QC Sample Results

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

Method: 9056A - Anions, Ion Chromatography

Lab Sample ID: MB 310-242591/3
Matrix: Water
Analysis Batch: 242591

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	<0.29		1.0	0.29	mg/L			06/10/19 11:27	1
Fluoride	<0.045		0.10	0.045	mg/L			06/10/19 11:27	1
Sulfate	<0.35		1.0	0.35	mg/L			06/10/19 11:27	1

Lab Sample ID: LCS 310-242591/4
Matrix: Water
Analysis Batch: 242591

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Chloride	10.0	10.3		mg/L		103	90 - 110
Fluoride	2.00	2.13		mg/L		107	90 - 110
Sulfate	10.0	10.5		mg/L		105	90 - 110

Method: 6020A - Metals (ICP/MS)

Lab Sample ID: MB 310-242330/1-A
Matrix: Water
Analysis Batch: 242461

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 242330

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		06/10/19 07:54	06/10/19 14:16	1
Arsenic	<0.75		2.0	0.75	ug/L		06/10/19 07:54	06/10/19 14:16	1
Barium	<0.84		2.0	0.84	ug/L		06/10/19 07:54	06/10/19 14:16	1
Beryllium	<0.27		1.0	0.27	ug/L		06/10/19 07:54	06/10/19 14:16	1
Boron	<110		200	110	ug/L		06/10/19 07:54	06/10/19 14:16	1
Cadmium	<0.077		0.50	0.077	ug/L		06/10/19 07:54	06/10/19 14:16	1
Calcium	<0.10		0.50	0.10	mg/L		06/10/19 07:54	06/10/19 14:16	1
Chromium	<0.98		5.0	0.98	ug/L		06/10/19 07:54	06/10/19 14:16	1
Cobalt	<0.091		0.50	0.091	ug/L		06/10/19 07:54	06/10/19 14:16	1
Lead	<0.27		0.50	0.27	ug/L		06/10/19 07:54	06/10/19 14:16	1
Lithium	<2.7		10	2.7	ug/L		06/10/19 07:54	06/10/19 14:16	1
Molybdenum	<1.1		2.0	1.1	ug/L		06/10/19 07:54	06/10/19 14:16	1
Selenium	<1.0		5.0	1.0	ug/L		06/10/19 07:54	06/10/19 14:16	1
Thallium	<0.27		1.0	0.27	ug/L		06/10/19 07:54	06/10/19 14:16	1

Lab Sample ID: LCS 310-242330/2-A
Matrix: Water
Analysis Batch: 242461

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 242330

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Antimony	20.0	18.7		ug/L		94	80 - 120
Arsenic	40.0	38.8		ug/L		97	80 - 120
Barium	40.0	40.6		ug/L		101	80 - 120
Beryllium	20.0	19.1		ug/L		95	80 - 120
Boron	880	815		ug/L		93	80 - 120
Cadmium	20.0	20.0		ug/L		100	80 - 120
Calcium	2.00	2.08		mg/L		104	80 - 120
Chromium	40.0	37.4		ug/L		94	80 - 120
Cobalt	20.0	19.2		ug/L		96	80 - 120

QC Sample Results

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

Method: 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: LCS 310-242330/2-A
Matrix: Water
Analysis Batch: 242461

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 242330

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	20.0	19.1		ug/L		95	80 - 120
Lithium	100	94.9		ug/L		95	80 - 120
Molybdenum	40.0	38.1		ug/L		95	80 - 120
Selenium	40.0	38.0		ug/L		95	80 - 120
Thallium	16.0	15.1		ug/L		94	80 - 120

Lab Sample ID: 310-157442-1 MS
Matrix: Water
Analysis Batch: 242461

Client Sample ID: Field Blank
Prep Type: Total/NA
Prep Batch: 242330

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Antimony	<0.53		20.0	20.2		ug/L		101	75 - 125
Arsenic	<0.75		40.0	43.1		ug/L		108	75 - 125
Barium	3.3		40.0	47.1		ug/L		109	75 - 125
Beryllium	<0.27		20.0	20.7		ug/L		103	75 - 125
Boron	<110		880	948		ug/L		108	75 - 125
Cadmium	<0.077		20.0	21.1		ug/L		106	75 - 125
Calcium	0.35	J	2.00	2.51		mg/L		108	75 - 125
Chromium	<0.98		40.0	41.0		ug/L		103	75 - 125
Cobalt	<0.091		20.0	21.0		ug/L		105	75 - 125
Lead	<0.27		20.0	20.2		ug/L		101	75 - 125
Lithium	<2.7		100	103		ug/L		103	75 - 125
Molybdenum	1.2	J	40.0	43.5		ug/L		106	75 - 125
Selenium	<1.0		40.0	41.3		ug/L		103	75 - 125
Thallium	<0.27		16.0	15.8		ug/L		99	75 - 125

Lab Sample ID: 310-157442-1 MSD
Matrix: Water
Analysis Batch: 242461

Client Sample ID: Field Blank
Prep Type: Total/NA
Prep Batch: 242330

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Antimony	<0.53		20.0	21.3		ug/L		106	75 - 125	5	20
Arsenic	<0.75		40.0	45.4		ug/L		113	75 - 125	5	20
Barium	3.3		40.0	48.9		ug/L		114	75 - 125	4	20
Beryllium	<0.27		20.0	21.5		ug/L		108	75 - 125	4	20
Boron	<110		880	1010		ug/L		115	75 - 125	6	20
Cadmium	<0.077		20.0	22.4		ug/L		112	75 - 125	6	20
Calcium	0.35	J	2.00	2.68		mg/L		116	75 - 125	6	20
Chromium	<0.98		40.0	43.7		ug/L		109	75 - 125	6	20
Cobalt	<0.091		20.0	22.1		ug/L		111	75 - 125	5	20
Lead	<0.27		20.0	21.3		ug/L		106	75 - 125	5	20
Lithium	<2.7		100	110		ug/L		110	75 - 125	6	20
Molybdenum	1.2	J	40.0	46.0		ug/L		112	75 - 125	6	20
Selenium	<1.0		40.0	44.2		ug/L		110	75 - 125	7	20
Thallium	<0.27		16.0	16.4		ug/L		103	75 - 125	4	20

Method: 7470A - Mercury (CVAA)

Lab Sample ID: MB 310-242147/1-A
Matrix: Water
Analysis Batch: 242440

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 242147

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.10		0.20	0.10	ug/L		06/07/19 09:40	06/10/19 13:16	1

Lab Sample ID: LCS 310-242147/2-A
Matrix: Water
Analysis Batch: 242440

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 242147

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Mercury	1.67	1.74		ug/L		104	80 - 120

Method: SM 2540C - Solids, Total Dissolved (TDS)

Lab Sample ID: MB 310-242168/1
Matrix: Water
Analysis Batch: 242168

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	<24		30	24	mg/L			06/07/19 11:09	1

Lab Sample ID: LCS 310-242168/2
Matrix: Water
Analysis Batch: 242168

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Total Dissolved Solids	1000	1010		mg/L		101	90 - 110

Method: SM 4500 H+ B - pH

Lab Sample ID: LCS 310-242253/1
Matrix: Water
Analysis Batch: 242253

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
pH	7.00	7.0		SU		100	98 - 102

QC Association Summary

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

HPLC/IC

Analysis Batch: 242591

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-157442-1	Field Blank	Total/NA	Water	9056A	
310-157442-2	MW-312	Total/NA	Water	9056A	
310-157442-3	MW-313	Total/NA	Water	9056A	
MB 310-242591/3	Method Blank	Total/NA	Water	9056A	
LCS 310-242591/4	Lab Control Sample	Total/NA	Water	9056A	

Metals

Prep Batch: 242147

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-157442-1	Field Blank	Total/NA	Water	7470A	
310-157442-2	MW-312	Total/NA	Water	7470A	
310-157442-3	MW-313	Total/NA	Water	7470A	
MB 310-242147/1-A	Method Blank	Total/NA	Water	7470A	
LCS 310-242147/2-A	Lab Control Sample	Total/NA	Water	7470A	

Prep Batch: 242330

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-157442-1	Field Blank	Total/NA	Water	3010A	
310-157442-2	MW-312	Total/NA	Water	3010A	
310-157442-3	MW-313	Total/NA	Water	3010A	
MB 310-242330/1-A	Method Blank	Total/NA	Water	3010A	
LCS 310-242330/2-A	Lab Control Sample	Total/NA	Water	3010A	
310-157442-1 MS	Field Blank	Total/NA	Water	3010A	
310-157442-1 MSD	Field Blank	Total/NA	Water	3010A	

Analysis Batch: 242440

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-157442-1	Field Blank	Total/NA	Water	7470A	242147
310-157442-2	MW-312	Total/NA	Water	7470A	242147
310-157442-3	MW-313	Total/NA	Water	7470A	242147
MB 310-242147/1-A	Method Blank	Total/NA	Water	7470A	242147
LCS 310-242147/2-A	Lab Control Sample	Total/NA	Water	7470A	242147

Analysis Batch: 242461

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-157442-1	Field Blank	Total/NA	Water	6020A	242330
310-157442-2	MW-312	Total/NA	Water	6020A	242330
310-157442-2	MW-312	Total/NA	Water	6020A	242330
310-157442-3	MW-313	Total/NA	Water	6020A	242330
310-157442-3	MW-313	Total/NA	Water	6020A	242330
MB 310-242330/1-A	Method Blank	Total/NA	Water	6020A	242330
LCS 310-242330/2-A	Lab Control Sample	Total/NA	Water	6020A	242330
310-157442-1 MS	Field Blank	Total/NA	Water	6020A	242330
310-157442-1 MSD	Field Blank	Total/NA	Water	6020A	242330

General Chemistry

Analysis Batch: 242168

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-157442-1	Field Blank	Total/NA	Water	SM 2540C	
310-157442-2	MW-312	Total/NA	Water	SM 2540C	

General Chemistry (Continued)

Analysis Batch: 242168 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-157442-3	MW-313	Total/NA	Water	SM 2540C	
MB 310-242168/1	Method Blank	Total/NA	Water	SM 2540C	
LCS 310-242168/2	Lab Control Sample	Total/NA	Water	SM 2540C	

Analysis Batch: 242253

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-157442-1	Field Blank	Total/NA	Water	SM 4500 H+ B	
310-157442-2	MW-312	Total/NA	Water	SM 4500 H+ B	
310-157442-3	MW-313	Total/NA	Water	SM 4500 H+ B	
LCS 310-242253/1	Lab Control Sample	Total/NA	Water	SM 4500 H+ B	

Field Service / Mobile Lab

Analysis Batch: 242586

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-157442-2	MW-312	Total/NA	Water	Field Sampling	
310-157442-3	MW-313	Total/NA	Water	Field Sampling	

Lab Chronicle

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

Client Sample ID: Field Blank

Lab Sample ID: 310-157442-1

Date Collected: 06/06/19 08:30
Date Received: 06/07/19 10:00

Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		1	242591	06/10/19 19:18	MLU	TAL CF
Total/NA	Prep	3010A			242330	06/10/19 07:54	HED	TAL CF
Total/NA	Analysis	6020A		1	242461	06/10/19 14:22	SAD	TAL CF
Total/NA	Prep	7470A			242147	06/10/19 08:32	JNR	TAL CF
Total/NA	Analysis	7470A		1	242440	06/10/19 13:44	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	242168	06/07/19 11:09	SAS	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	242253	06/07/19 21:50	JMH	TAL CF

Client Sample ID: MW-312

Lab Sample ID: 310-157442-2

Date Collected: 06/06/19 09:00
Date Received: 06/07/19 10:00

Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	242591	06/10/19 20:05	MLU	TAL CF
Total/NA	Prep	3010A			242330	06/10/19 07:54	HED	TAL CF
Total/NA	Analysis	6020A		1	242461	06/10/19 14:36	SAD	TAL CF
Total/NA	Prep	3010A			242330	06/10/19 07:54	HED	TAL CF
Total/NA	Analysis	6020A		4	242461	06/10/19 14:43	SAD	TAL CF
Total/NA	Prep	7470A			242147	06/10/19 08:32	JNR	TAL CF
Total/NA	Analysis	7470A		1	242440	06/10/19 13:46	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	242168	06/07/19 11:09	SAS	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	242253	06/07/19 21:54	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	242586	06/06/19 09:00	EAR	TAL CF

Client Sample ID: MW-313

Lab Sample ID: 310-157442-3

Date Collected: 06/06/19 11:30
Date Received: 06/07/19 10:00

Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	242591	06/10/19 20:20	MLU	TAL CF
Total/NA	Prep	3010A			242330	06/10/19 07:54	HED	TAL CF
Total/NA	Analysis	6020A		1	242461	06/10/19 14:39	SAD	TAL CF
Total/NA	Prep	3010A			242330	06/10/19 07:54	HED	TAL CF
Total/NA	Analysis	6020A		4	242461	06/10/19 14:46	SAD	TAL CF
Total/NA	Prep	7470A			242147	06/10/19 08:32	JNR	TAL CF
Total/NA	Analysis	7470A		1	242440	06/10/19 13:48	JNR	TAL CF
Total/NA	Analysis	SM 2540C		1	242168	06/07/19 11:09	SAS	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	242253	06/07/19 21:58	JMH	TAL CF
Total/NA	Analysis	Field Sampling		1	242586	06/06/19 11:30	EAR	TAL CF

Laboratory References:

TAL CF = Eurofins TestAmerica, Cedar Falls, 3019 Venture Way, Cedar Falls, IA 50613, TEL (319)277-2401

Accreditation/Certification Summary

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

Laboratory: Eurofins TestAmerica, Cedar Falls

The accreditations/certifications listed below are applicable to this report.

Authority	Program	EPA Region	Identification Number	Expiration Date
Iowa	State Program	7	007	12-01-19

Method Summary

Client: SCS Engineers
Project/Site: Alliant Burlington 25218220

Job ID: 310-157442-1

Method	Method Description	Protocol	Laboratory
9056A	Anions, Ion Chromatography	SW846	TAL CF
6020A	Metals (ICP/MS)	SW846	TAL CF
7470A	Mercury (CVAA)	SW846	TAL CF
SM 2540C	Solids, Total Dissolved (TDS)	SM	TAL CF
SM 4500 H+ B	pH	SM	TAL CF
Field Sampling	Field Sampling	EPA	TAL CF
3010A	Preparation, Total Metals	SW846	TAL CF
7470A	Preparation, Mercury	SW846	TAL CF

Protocol References:

EPA = US Environmental Protection Agency

SM = "Standard Methods For The Examination Of Water And Wastewater"

SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

Laboratory References:

TAL CF = Eurofins TestAmerica, Cedar Falls, 3019 Venture Way, Cedar Falls, IA 50613, TEL (319)277-2401

Table 3. Parameters for Groundwater Monitoring to meet Federal Requirements

Appendix III	Boron
	Calcium
	Chloride
	Fluoride
	pH
	Sulfate
	TDS
Appendix IV	Antimony
	Arsenic
	Barium
	Beryllium
	Cadmium
	Chromium
	Cobalt
	Fluoride
	Lead
	Lithium
	Mercury
	Molybdenum
	Selenium
	Thallium
	Radium

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

310-157442 Chain of Custody

Cooler/Sample Receipt and Temperature Log Form

Client Information

Client: SCS Engineers

City/State: CITY Menomonee Falls STATE WI | Project: Alliant Burlington

Receipt Information

Date/Time Received: DATE 6-7-19 TIME 1000 | Received By: LAB

Delivery Type: ☐ UPS ☒ FedEx ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee ☐ Lab Courier ☐ TA Field Services ☐ Client Drop-off ☐ Other:

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes ☐ No	*If yes:* Cooler ID:	
Multiple Coolers?	☐ Yes ☒ No	*If yes:* Cooler # ____ of ____	
Cooler Custody Seals Present?	☐ Yes ☒ No	*If yes:* Cooler custody seals intact?	☐ Yes ☐ No
Sample Custody Seals Present?	☐ Yes ☒ No	*If yes:* Sample custody seals intact?	☐ Yes ☐ No
Trip Blank Present?	☐ Yes ☒ No	*If yes:* Which VOA samples are in cooler? ↓	

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other: ☐ NONE

Thermometer ID: 1 | Correction Factor (°C): -0.1

• Temp Blank Temperature – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): 3.9 | Corrected Temp (°C): 3.8

• Sample Container Temperature

Container type(s) used: CONTAINER 1 | CONTAINER 2

Uncorrected Temp (°C): TEMP 1 | TEMP 2 | Corrected Temp (°C): TEMP 1 | TEMP 2

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

Document: CF-LG-WI-002
Revision: 24
Date: 03/07/2019

TestAmerica-Cedar Falls

General temperature criteria is 0 to 6°C
Bacteria temperature criteria is 0 to 10°C

Eurofins TestAmerica, Cedar Falls
704 Enterprise Drive
Cedar Falls, IA 50613
Phone: 319-277-2401 Fax: 319-277-2425

Chain of Custody Record

TestAmerica Des Moines SC 214

eurofins | Environment Testing TestAmerica

#4045940

Client Information	Sampler: Zach Watson	Lab PM: Fredrick, Sandie	Carrier Tracking No(s):	COC No: 310-40460-13155.1
Client Contact: Gary Sterkel	Phone: 262 271 3744	E-Mail: sandie.fredrick@testamericainc.com		Page: Page 1 of 1
Company: SCS Engineers				Job #:
Address: N84 W13540 Leon Road	Due Date Requested:			
City: Menomonee Falls	TAT Requested (days):			
State, Zip: WI, 53051				
Phone:	PO #: 25218220			
Email: gsterkel@scsengineers.com	WO #:			
Project Name: Alliant Burlington 25218220	Project #: 31011020			
Site:	SSOW#:			

Analysis Requested

Preservation Codes:
A - HCL, M - Hexane
B - NaOH, N - None
C - Zn Acetate, O - AsNaO2
D - Nitric Acid, P - Na2O4S
E - NaHSO4, Q - Na2SO3
F - MeOH, R - Na2S2O3
G - Amchlor, S - H2SO4
H - Ascorbic Acid, T - TSP Dodecahydrate
I - Ice, U - Acetone
J - DI Water, V - MCAA
K - EDTA, W - pH 4-5
L - EDA, Z - other (specify)
Other:

Sample Identification	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	6020A, 7470A	2540C_Calcd, 9056A_ORGFM_28D, SM4500_H+	903.0 - Radium 226	904.0 - Radium 228	Total Number of containers	Special Instructions/Note:
			Preservation Code:				D	N	D	D		
MW-301 Field Blank	6.6.19	830	G	Water			X	X	X	X		RUSH!
MW-302 MW312	6.6.19	900	↓	Water			X	X	X	X		RUSH!
MW-303 MW313	6.6.19	1130	↓	Water			X	X	X	X		RUSH!

Possible Hazard Identification
☐ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown ☐ Radiological

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months

Deliverable Requested: I, II, III, IV, Other (specify)

Special Instructions/QC Requirements:

Empty Kit Relinquished by:		Date:	Time:	Method of Shipment:	
Relinquished by: [signature]	Date/Time: 6.6.19 1200	Company: SCS	Received by: Lindsay Bindert	Date/Time: 6-7-19 1000	Company:
Relinquished by:	Date/Time:	Company:	Received by:	Date/Time:	Company:
Relinquished by:	Date/Time:	Company:	Received by:	Date/Time:	Company:

Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:	Cooler Temperature(s) °C and Other Remarks:

Ver: 01/16/2019

Login Container Summary Report

310-157442

Temperature readings: ______________________________

Client Sample ID	Lab ID	Container Type	Container pH	Preservative Added (mls)	Lot #
Field Blank	310-157442-A-1	Plastic 250ml - with Nitric Acid	<2		
Field Blank	310-157442-C-1	Plastic 1 liter - Nitric Acid	<2		
Field Blank	310-157442-D-1	Plastic 1 liter - Nitric Acid	<2		
MW312	310-157442-A-2	Plastic 250ml - with Nitric Acid	<2		
MW312	310-157442-C-2	Plastic 1 liter - Nitric Acid	<2		
MW312	310-157442-D-2	Plastic 1 liter - Nitric Acid	<2		
MW313	310-157442-A-3	Plastic 250ml - with Nitric Acid	<2		
MW313	310-157442-C-3	Plastic 1 liter - Nitric Acid	<2		
MW313	310-157442-D-3	Plastic 1 liter - Nitric Acid	<2		

Login Sample Receipt Checklist

Client: SCS Engineers

Job Number: 310-157442-1

Login Number: 157442
List Number: 1
Creator: Bindert, Lindsay A

List Source: Eurofins TestAmerica, Cedar Falls

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	N/A	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

A3 Assessment Monitoring, October 2019

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ANALYTICAL REPORT

Eurofins TestAmerica, Cedar Falls
3019 Venture Way
Cedar Falls, IA 50613
Tel: (319)277-2401

Laboratory Job ID: 310-167314-1
Client Project/Site: Burlington Gen Station 25216066

For:
SCS Engineers
2830 Dairy Drive
Madison, Wisconsin 53718

Attn: Meghan Blodgett

Authorized for release by:
10/28/2019 9:33:36 AM

Sandie Fredrick, Project Manager II
(920)261-1660
sandie.fredrick@testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Case Narrative

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Job ID: 310-167314-1

Laboratory: Eurofins TestAmerica, Cedar Falls

Narrative

Job Narrative
310-167314-1

Comments
No additional comments.

Receipt
The samples were received on 10/12/2019 9:45 AM; the samples arrived in good condition, properly preserved and, where required, on ice. The temperatures of the 3 coolers at receipt time were 0.1º C, 0.5º C and 1.3º C.

HPLC/IC
Methods 300.0, 9056A: The following samples were diluted due to the nature of the sample matrix: MW-301 (310-167314-1), MW-302 (310-167314-2), MW-303 (310-167314-3), MW-304 (310-167314-4), MW-305 (310-167314-5), MW-306 (310-167314-6), MW-307 (310-167314-7), MW-308 (310-167314-8), MW-309 (310-167314-9), MW-310 (310-167314-10), MW-311 (310-167314-11), MW-312 (310-167314-12) and MW-313 (310-167314-13). Elevated reporting limits (RLs) are provided.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

Metals
Method 6020A: Due to sample matrix effect on the internal standard (ISTD), a dilution was required for the following samples: MW-309 (310-167314-9), MW-312 (310-167314-12) and MW-313 (310-167314-13).

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

General Chemistry
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Sample Summary

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received	Asset ID
310-167314-1	MW-301	Water	10/10/19 11:02	10/12/19 09:45	
310-167314-2	MW-302	Water	10/10/19 12:12	10/12/19 09:45	
310-167314-3	MW-303	Water	10/10/19 13:00	10/12/19 09:45	
310-167314-4	MW-304	Water	10/10/19 13:44	10/12/19 09:45	
310-167314-5	MW-305	Water	10/11/19 10:30	10/12/19 09:45	
310-167314-6	MW-306	Water	10/11/19 11:16	10/12/19 09:45	
310-167314-7	MW-307	Water	10/11/19 15:06	10/12/19 09:45	
310-167314-8	MW-308	Water	10/10/19 10:08	10/12/19 09:45	
310-167314-9	MW-309	Water	10/11/19 09:44	10/12/19 09:45	
310-167314-10	MW-310	Water	10/11/19 08:02	10/12/19 09:45	
310-167314-11	MW-311	Water	10/11/19 08:54	10/12/19 09:45	
310-167314-12	MW-312	Water	10/10/19 15:22	10/12/19 09:45	
310-167314-13	MW-313	Water	10/10/19 14:36	10/12/19 09:45	
310-167314-14	Field Blank	Water	10/10/19 23:59	10/12/19 09:45	

Detection Summary

Client: SCS Engineers
Job ID: 310-167314-1
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-301
Lab Sample ID: 310-167314-1

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	20		5.0	1.5	mg/L	5		9056A	Total/NA
Sulfate	390		20	7.0	mg/L	20		9056A	Total/NA
Arsenic	40		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	320		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	8100		800	440	ug/L	4		6020A	Total/NA
Calcium	130		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.18	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lithium	26		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	130		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	690		150	120	mg/L	1		SM 2540C	Total/NA
pH	7.1	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-162.9				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.23				mg/L	1		Field Sampling	Total/NA
pH, Field	6.85				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	1063				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	13.9				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	12.55				NTU	1		Field Sampling	Total/NA

Client Sample ID: MW-302
Lab Sample ID: 310-167314-2

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	11		5.0	1.5	mg/L	5		9056A	Total/NA
Sulfate	510		20	7.0	mg/L	20		9056A	Total/NA
Arsenic	73		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	260		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	11000		800	440	ug/L	4		6020A	Total/NA
Calcium	220		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.23	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lithium	57		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	100		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	960		150	120	mg/L	1		SM 2540C	Total/NA
pH	7.7	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-186.8				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.28				mg/L	1		Field Sampling	Total/NA
pH, Field	7.49				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	1249				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	14.46				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	1.16				NTU	1		Field Sampling	Total/NA

Client Sample ID: MW-303
Lab Sample ID: 310-167314-3

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	16		5.0	1.5	mg/L	5		9056A	Total/NA
Sulfate	84		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	17		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	440		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	21000		2000	1100	ug/L	10		6020A	Total/NA
Calcium	91		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.45	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lithium	46		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	76		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	420		150	120	mg/L	1		SM 2540C	Total/NA

This Detection Summary does not include radiochemical test results.

Eurofins TestAmerica, Cedar Falls

Detection Summary

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Client Sample ID: MW-303 (Continued)

Lab Sample ID: 310-167314-3

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
pH	7.4	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-161.0				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.26				mg/L	1		Field Sampling	Total/NA
pH, Field	7.13				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	767				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	14.91				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	5.36				NTU	1		Field Sampling	Total/NA

Client Sample ID: MW-304

Lab Sample ID: 310-167314-4

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	25		5.0	1.5	mg/L	5		9056A	Total/NA
Sulfate	220		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	36		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	210		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	5100		800	440	ug/L	4		6020A	Total/NA
Calcium	140		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.13	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lithium	38		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	47		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	710		150	120	mg/L	1		SM 2540C	Total/NA
pH	7.5	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-157.5				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.28				mg/L	1		Field Sampling	Total/NA
pH, Field	7.17				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	934				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	15.64				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	1.18				NTU	1		Field Sampling	Total/NA

Client Sample ID: MW-305

Lab Sample ID: 310-167314-5

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	33		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.37	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	8.8		5.0	1.8	mg/L	5		9056A	Total/NA
Barium	180		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	2100		400	220	ug/L	2		6020A	Total/NA
Calcium	90		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.13	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lithium	26		10	2.7	ug/L	1		6020A	Total/NA
Total Dissolved Solids	490		150	120	mg/L	1		SM 2540C	Total/NA
pH	7.5	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-132.9				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.20				mg/L	1		Field Sampling	Total/NA
pH, Field	7.36				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	795				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	14.29				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	3.02				NTU	1		Field Sampling	Total/NA

This Detection Summary does not include radiochemical test results.

Detection Summary

Client: SCS Engineers
Job ID: 310-167314-1
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-306 — Lab Sample ID: 310-167314-6

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	20		5.0	1.5	mg/L	5		9056A	Total/NA
Sulfate	110		5.0	1.8	mg/L	5		9056A	Total/NA
Antimony	1.2		1.0	0.53	ug/L	1		6020A	Total/NA
Arsenic	46		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	14		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	3100		400	220	ug/L	2		6020A	Total/NA
Calcium	38		0.50	0.10	mg/L	1		6020A	Total/NA
Lead	0.44	J	0.50	0.27	ug/L	1		6020A	Total/NA
Lithium	46		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	84		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	290		30	24	mg/L	1		SM 2540C	Total/NA
pH	10.5	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-165.1				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.21				mg/L	1		Field Sampling	Total/NA
pH, Field	10.53				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	473				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	14.28				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	1.84				NTU	1		Field Sampling	Total/NA

Client Sample ID: MW-307 — Lab Sample ID: 310-167314-7

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	19		5.0	1.5	mg/L	5		9056A	Total/NA
Sulfate	130		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	47		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	31		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	3700		400	220	ug/L	2		6020A	Total/NA
Calcium	31		0.50	0.10	mg/L	1		6020A	Total/NA
Lead	0.41	J	0.50	0.27	ug/L	1		6020A	Total/NA
Lithium	48		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	130		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	340		30	24	mg/L	1		SM 2540C	Total/NA
pH	10.2	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-126.3				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.24				mg/L	1		Field Sampling	Total/NA
pH, Field	10.14				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	536				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	14.37				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	3.23				NTU	1		Field Sampling	Total/NA

Client Sample ID: MW-308 — Lab Sample ID: 310-167314-8

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	40		5.0	1.5	mg/L	5		9056A	Total/NA
Sulfate	160		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	72		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	70		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	4500		400	220	ug/L	2		6020A	Total/NA
Calcium	30		0.50	0.10	mg/L	1		6020A	Total/NA
Lithium	52		10	2.7	ug/L	1		6020A	Total/NA
Molybdenum	120		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	400		150	120	mg/L	1		SM 2540C	Total/NA

This Detection Summary does not include radiochemical test results.

Detection Summary

Client: SCS Engineers	Job ID: 310-167314-1
Project/Site: Burlington Gen Station 25216066

## Client Sample ID: MW-308 (Continued)	Lab Sample ID: 310-167314-8

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
pH	9.9	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-82.6				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.21				mg/L	1		Field Sampling	Total/NA
pH, Field	9.42				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	671				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	14.64				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	2.93				NTU	1		Field Sampling	Total/NA

## Client Sample ID: MW-309	Lab Sample ID: 310-167314-9

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	74		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.29	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	160		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	34		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	180		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	4300		400	220	ug/L	2		6020A	Total/NA
Calcium	68		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.52		0.50	0.091	ug/L	1		6020A	Total/NA
Molybdenum	90		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	610		60	48	mg/L	1		SM 2540C	Total/NA
pH	7.2	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-165.6				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.21				mg/L	1		Field Sampling	Total/NA
pH, Field	7.19				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	1040				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	13.73				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	8.93				NTU	1		Field Sampling	Total/NA

## Client Sample ID: MW-310	Lab Sample ID: 310-167314-10

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	59		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.34	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	51		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	61		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	500		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	380		200	110	ug/L	1		6020A	Total/NA
Calcium	120		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	1.9		0.50	0.091	ug/L	1		6020A	Total/NA
Molybdenum	6.0		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	410		60	48	mg/L	1		SM 2540C	Total/NA
pH	7.2	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-189.7				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.28				mg/L	1		Field Sampling	Total/NA
pH, Field	6.95				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	961				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	15.88				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	5.23				NTU	1		Field Sampling	Total/NA

This Detection Summary does not include radiochemical test results.

Detection Summary

Client: SCS Engineers
Job ID: 310-167314-1
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-311 — Lab Sample ID: 310-167314-11

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	65		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.37	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	130		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	18		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	210		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	2800		200	110	ug/L	1		6020A	Total/NA
Calcium	150		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.27	J	0.50	0.091	ug/L	1		6020A	Total/NA
Molybdenum	15		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	590		60	48	mg/L	1		SM 2540C	Total/NA
pH	7.2	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-163.4				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.30				mg/L	1		Field Sampling	Total/NA
pH, Field	7.07				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	1088				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	14.19				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	13.4				NTU	1		Field Sampling	Total/NA

Client Sample ID: MW-312 — Lab Sample ID: 310-167314-12

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	25		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.25	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	230		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	15		4.0	1.5	ug/L	2		6020A	Total/NA
Barium	150		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	6600		400	220	ug/L	2		6020A	Total/NA
Cadmium	0.044	J	0.10	0.039	ug/L	1		6020A	Total/NA
Calcium	71		1.0	0.20	mg/L	2		6020A	Total/NA
Cobalt	0.36	J	0.50	0.091	ug/L	1		6020A	Total/NA
Lithium	27		20	5.4	ug/L	2		6020A	Total/NA
Molybdenum	280		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	510		150	120	mg/L	1		SM 2540C	Total/NA
pH	7.3	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-163.8				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	8.75				mg/L	1		Field Sampling	Total/NA
pH, Field	7.19				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	785				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	15.6				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	2.56				NTU	1		Field Sampling	Total/NA

Client Sample ID: MW-313 — Lab Sample ID: 310-167314-13

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Chloride	51		5.0	1.5	mg/L	5		9056A	Total/NA
Fluoride	0.28	J	0.50	0.23	mg/L	5		9056A	Total/NA
Sulfate	210		5.0	1.8	mg/L	5		9056A	Total/NA
Arsenic	6.3		2.0	0.75	ug/L	1		6020A	Total/NA
Barium	490		2.0	0.84	ug/L	1		6020A	Total/NA
Boron	8500		800	440	ug/L	4		6020A	Total/NA
Calcium	120		0.50	0.10	mg/L	1		6020A	Total/NA
Cobalt	0.32	J	0.50	0.091	ug/L	1		6020A	Total/NA

This Detection Summary does not include radiochemical test results.

Client Sample ID: MW-313 (Continued) — Lab Sample ID: 310-167314-13

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Lead	0.31	J	0.50	0.27	ug/L	1		6020A	Total/NA
Lithium	62		40	11	ug/L	4		6020A	Total/NA
Molybdenum	110		2.0	1.1	ug/L	1		6020A	Total/NA
Total Dissolved Solids	520		150	120	mg/L	1		SM 2540C	Total/NA
pH	7.2	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA
Oxidation Reduction Potential	-163.4				millivolts	1		Field Sampling	Total/NA
Oxygen, Dissolved, Client Supplied	0.37				mg/L	1		Field Sampling	Total/NA
pH, Field	7.06				SU	1		Field Sampling	Total/NA
Specific Conductance, Field	1007				umhos/cm	1		Field Sampling	Total/NA
Temperature, Field	16.04				Degrees C	1		Field Sampling	Total/NA
Turbidity, Field	11.03				NTU	1		Field Sampling	Total/NA

Client Sample ID: Field Blank — Lab Sample ID: 310-167314-14

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
pH	5.7	HF	0.1	0.1	SU	1		SM 4500 H+ B	Total/NA

This Detection Summary does not include radiochemical test results.

Client Sample Results

Client: SCS Engineers Job ID: 310-167314-1
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-301 **Lab Sample ID: 310-167314-1**
Date Collected: 10/10/19 11:02 **Matrix: Water**
Date Received: 10/12/19 09:45

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**20**		5.0	1.5	mg/L			10/21/19 12:20	5
Fluoride	<0.23		0.50	0.23	mg/L			10/21/19 12:20	5
Sulfate	**390**		20	7.0	mg/L			10/21/19 17:43	20

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 21:50	1
Arsenic	**40**		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 21:50	1
Barium	**320**		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 21:50	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/16/19 21:50	1
Boron	**8100**		800	440	ug/L		10/15/19 07:39	10/17/19 12:37	4
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 21:50	1
Calcium	**130**		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 21:50	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 21:50	1
Cobalt	**0.18**	**J**	0.50	0.091	ug/L		10/15/19 07:39	10/16/19 21:50	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 21:50	1
Lithium	**26**		10	2.7	ug/L		10/15/19 07:39	10/16/19 21:50	1
Molybdenum	**130**		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 21:50	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 21:50	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**690**		150	120	mg/L			10/16/19 10:06	1
pH	**7.1**	**HF**	0.1	0.1	SU			10/12/19 12:01	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-162.9**				millivolts			10/10/19 11:02	1
Oxygen, Dissolved, Client Supplied	**0.23**				mg/L			10/10/19 11:02	1
pH, Field	**6.85**				SU			10/10/19 11:02	1
Specific Conductance, Field	**1063**				umhos/cm			10/10/19 11:02	1
Temperature, Field	**13.9**				Degrees C			10/10/19 11:02	1
Turbidity, Field	**12.55**				NTU			10/10/19 11:02	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Client Sample ID: MW-302

Date Collected: 10/10/19 12:12
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-2
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**11**		5.0	1.5	mg/L			10/21/19 12:35	5
Fluoride	<0.23		0.50	0.23	mg/L			10/21/19 12:35	5
Sulfate	**510**		20	7.0	mg/L			10/21/19 17:59	20

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 22:17	1
Arsenic	**73**		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 22:17	1
Barium	**260**		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 22:17	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/16/19 22:17	1
Boron	**11000**		800	440	ug/L		10/15/19 07:39	10/17/19 12:45	4
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 22:17	1
Calcium	**220**		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 22:17	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 22:17	1
Cobalt	**0.23**	**J**	0.50	0.091	ug/L		10/15/19 07:39	10/16/19 22:17	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 22:17	1
Lithium	**57**		10	2.7	ug/L		10/15/19 07:39	10/16/19 22:17	1
Molybdenum	**100**		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 22:17	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 22:17	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**960**		150	120	mg/L			10/16/19 10:06	1
pH	**7.7**	**HF**	0.1	0.1	SU			10/12/19 11:55	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-186.8**				millivolts			10/10/19 12:12	1
Oxygen, Dissolved, Client Supplied	**0.28**				mg/L			10/10/19 12:12	1
pH, Field	**7.49**				SU			10/10/19 12:12	1
Specific Conductance, Field	**1249**				umhos/cm			10/10/19 12:12	1
Temperature, Field	**14.46**				Degrees C			10/10/19 12:12	1
Turbidity, Field	**1.16**				NTU			10/10/19 12:12	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Client Sample ID: MW-303
Date Collected: 10/10/19 13:00
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-3
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**16**		5.0	1.5	mg/L			10/21/19 12:51	5
Fluoride	<0.23		0.50	0.23	mg/L			10/21/19 12:51	5
Sulfate	**84**		5.0	1.8	mg/L			10/21/19 12:51	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 22:21	1
Arsenic	**17**		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 22:21	1
Barium	**440**		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 22:21	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/16/19 22:21	1
Boron	**21000**		2000	1100	ug/L		10/15/19 07:39	10/17/19 12:47	10
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 22:21	1
Calcium	**91**		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 22:21	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 22:21	1
Cobalt	**0.45**	**J**	0.50	0.091	ug/L		10/15/19 07:39	10/16/19 22:21	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 22:21	1
Lithium	**46**		10	2.7	ug/L		10/15/19 07:39	10/16/19 22:21	1
Molybdenum	**76**		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 22:21	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 22:21	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**420**		150	120	mg/L			10/16/19 10:06	1
pH	**7.4**	**HF**	0.1	0.1	SU			10/12/19 11:53	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-161.0**				millivolts			10/10/19 13:00	1
Oxygen, Dissolved, Client Supplied	**0.26**				mg/L			10/10/19 13:00	1
pH, Field	**7.13**				SU			10/10/19 13:00	1
Specific Conductance, Field	**767**				umhos/cm			10/10/19 13:00	1
Temperature, Field	**14.91**				Degrees C			10/10/19 13:00	1
Turbidity, Field	**5.36**				NTU			10/10/19 13:00	1

Client Sample ID: MW-304

Lab Sample ID: 310-167314-4

Date Collected: 10/10/19 13:44

Matrix: Water

Date Received: 10/12/19 09:45

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**25**		5.0	1.5	mg/L			10/21/19 13:06	5
Fluoride	<0.23		0.50	0.23	mg/L			10/21/19 13:06	5
Sulfate	**220**		5.0	1.8	mg/L			10/21/19 13:06	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 22:24	1
Arsenic	**36**		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 22:24	1
Barium	**210**		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 22:24	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/16/19 22:24	1
Boron	**5100**		800	440	ug/L		10/15/19 07:39	10/17/19 12:50	4
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 22:24	1
Calcium	**140**		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 22:24	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 22:24	1
Cobalt	**0.13**	**J**	0.50	0.091	ug/L		10/15/19 07:39	10/16/19 22:24	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 22:24	1
Lithium	**38**		10	2.7	ug/L		10/15/19 07:39	10/16/19 22:24	1
Molybdenum	**47**		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 22:24	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 22:24	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**710**		150	120	mg/L			10/16/19 10:06	1
pH	**7.5**	**HF**	0.1	0.1	SU			10/12/19 11:51	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-157.5**				millivolts			10/10/19 13:44	1
Oxygen, Dissolved, Client Supplied	**0.28**				mg/L			10/10/19 13:44	1
pH, Field	**7.17**				SU			10/10/19 13:44	1
Specific Conductance, Field	**934**				umhos/cm			10/10/19 13:44	1
Temperature, Field	**15.64**				Degrees C			10/10/19 13:44	1
Turbidity, Field	**1.18**				NTU			10/10/19 13:44	1

Client Sample Results

Client: SCS Engineers | Job ID: 310-167314-1
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-305 | Lab Sample ID: 310-167314-5

Date Collected: 10/11/19 10:30 | **Matrix: Water**
Date Received: 10/12/19 09:45

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**33**		5.0	1.5	mg/L			10/21/19 13:22	5
Fluoride	**0.37**	**J**	0.50	0.23	mg/L			10/21/19 13:22	5
Sulfate	**8.8**		5.0	1.8	mg/L			10/21/19 13:22	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 22:28	1
Arsenic	<0.75		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 22:28	1
Barium	**180**		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 22:28	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/16/19 22:28	1
Boron	**2100**		400	220	ug/L		10/15/19 07:39	10/17/19 12:53	2
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 22:28	1
Calcium	**90**		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 22:28	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 22:28	1
Cobalt	**0.13**	**J**	0.50	0.091	ug/L		10/15/19 07:39	10/16/19 22:28	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 22:28	1
Lithium	**26**		10	2.7	ug/L		10/15/19 07:39	10/16/19 22:28	1
Molybdenum	<1.1		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 22:28	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 22:28	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**490**		150	120	mg/L			10/16/19 10:06	1
pH	**7.5**	**HF**	0.1	0.1	SU			10/12/19 11:49	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-132.9**				millivolts			10/11/19 10:30	1
Oxygen, Dissolved, Client Supplied	**0.20**				mg/L			10/11/19 10:30	1
pH, Field	**7.36**				SU			10/11/19 10:30	1
Specific Conductance, Field	**795**				umhos/cm			10/11/19 10:30	1
Temperature, Field	**14.29**				Degrees C			10/11/19 10:30	1
Turbidity, Field	**3.02**				NTU			10/11/19 10:30	1

Client Sample ID: MW-306
Date Collected: 10/11/19 11:16
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-6
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**20**		5.0	1.5	mg/L			10/21/19 13:38	5
Fluoride	<0.23		0.50	0.23	mg/L			10/21/19 13:38	5
Sulfate	**110**		5.0	1.8	mg/L			10/21/19 13:38	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	**1.2**		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 22:31	1
Arsenic	**46**		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 22:31	1
Barium	**14**		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 22:31	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/16/19 22:31	1
Boron	**3100**		400	220	ug/L		10/15/19 07:39	10/17/19 12:55	2
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 22:31	1
Calcium	**38**		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 22:31	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 22:31	1
Cobalt	<0.091		0.50	0.091	ug/L		10/15/19 07:39	10/16/19 22:31	1
Lead	**0.44**	**J**	0.50	0.27	ug/L		10/15/19 07:39	10/16/19 22:31	1
Lithium	**46**		10	2.7	ug/L		10/15/19 07:39	10/16/19 22:31	1
Molybdenum	**84**		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 22:31	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 22:31	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**290**		30	24	mg/L			10/18/19 11:40	1
pH	**10.5**	**HF**	0.1	0.1	SU			10/12/19 11:48	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-165.1**				millivolts			10/11/19 11:16	1
Oxygen, Dissolved, Client Supplied	**0.21**				mg/L			10/11/19 11:16	1
pH, Field	**10.53**				SU			10/11/19 11:16	1
Specific Conductance, Field	**473**				umhos/cm			10/11/19 11:16	1
Temperature, Field	**14.28**				Degrees C			10/11/19 11:16	1
Turbidity, Field	**1.84**				NTU			10/11/19 11:16	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Client Sample ID: MW-307

Date Collected: 10/11/19 15:06
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-7
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**19**		5.0	1.5	mg/L			10/21/19 14:09	5
Fluoride	<0.23		0.50	0.23	mg/L			10/21/19 14:09	5
Sulfate	**130**		5.0	1.8	mg/L			10/21/19 14:09	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 22:34	1
Arsenic	**47**		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 22:34	1
Barium	**31**		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 22:34	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/16/19 22:34	1
Boron	**3700**		400	220	ug/L		10/15/19 07:39	10/17/19 12:58	2
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 22:34	1
Calcium	**31**		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 22:34	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 22:34	1
Cobalt	<0.091		0.50	0.091	ug/L		10/15/19 07:39	10/16/19 22:34	1
Lead	**0.41**	**J**	0.50	0.27	ug/L		10/15/19 07:39	10/16/19 22:34	1
Lithium	**48**		10	2.7	ug/L		10/15/19 07:39	10/16/19 22:34	1
Molybdenum	**130**		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 22:34	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 22:34	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**340**		30	24	mg/L			10/18/19 11:40	1
pH	**10.2**	**HF**	0.1	0.1	SU			10/12/19 11:46	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-126.3**				millivolts			10/11/19 15:06	1
Oxygen, Dissolved, Client Supplied	**0.24**				mg/L			10/11/19 15:06	1
pH, Field	**10.14**				SU			10/11/19 15:06	1
Specific Conductance, Field	**536**				umhos/cm			10/11/19 15:06	1
Temperature, Field	**14.37**				Degrees C			10/11/19 15:06	1
Turbidity, Field	**3.23**				NTU			10/11/19 15:06	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Client Sample ID: MW-308

Date Collected: 10/10/19 10:08
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-8
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**40**		5.0	1.5	mg/L			10/21/19 14:24	5
Fluoride	<0.23		0.50	0.23	mg/L			10/21/19 14:24	5
Sulfate	**160**		5.0	1.8	mg/L			10/21/19 14:24	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 22:48	1
Arsenic	**72**		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 22:48	1
Barium	**70**		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 22:48	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/16/19 22:48	1
Boron	**4500**		400	220	ug/L		10/15/19 07:39	10/17/19 13:01	2
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 22:48	1
Calcium	**30**		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 22:48	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 22:48	1
Cobalt	<0.091		0.50	0.091	ug/L		10/15/19 07:39	10/16/19 22:48	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 22:48	1
Lithium	**52**		10	2.7	ug/L		10/15/19 07:39	10/16/19 22:48	1
Molybdenum	**120**		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 22:48	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 22:48	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**400**		150	120	mg/L			10/16/19 10:06	1
pH	**9.9**	**HF**	0.1	0.1	SU			10/12/19 11:44	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-82.6**				millivolts			10/10/19 10:08	1
Oxygen, Dissolved, Client Supplied	**0.21**				mg/L			10/10/19 10:08	1
pH, Field	**9.42**				SU			10/10/19 10:08	1
Specific Conductance, Field	**671**				umhos/cm			10/10/19 10:08	1
Temperature, Field	**14.64**				Degrees C			10/10/19 10:08	1
Turbidity, Field	**2.93**				NTU			10/10/19 10:08	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Client Sample ID: MW-309
Date Collected: 10/11/19 09:44
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-9
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**74**		5.0	1.5	mg/L			10/21/19 14:40	5
Fluoride	**0.29**	**J**	0.50	0.23	mg/L			10/21/19 14:40	5
Sulfate	**160**		5.0	1.8	mg/L			10/21/19 14:40	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 22:52	1
Arsenic	**34**		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 22:52	1
Barium	**180**		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 22:52	1
Beryllium	<0.54		2.0	0.54	ug/L		10/15/19 07:39	10/17/19 13:11	2
Boron	**4300**		400	220	ug/L		10/15/19 07:39	10/17/19 13:11	2
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 22:52	1
Calcium	**68**		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 22:52	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 22:52	1
Cobalt	**0.52**		0.50	0.091	ug/L		10/15/19 07:39	10/16/19 22:52	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 22:52	1
Lithium	<5.4		20	5.4	ug/L		10/15/19 07:39	10/17/19 13:11	2
Molybdenum	**90**		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 22:52	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 22:52	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**610**		60	48	mg/L			10/18/19 11:40	1
pH	**7.2**	**HF**	0.1	0.1	SU			10/12/19 11:42	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-165.6**				millivolts			10/11/19 09:44	1
Oxygen, Dissolved, Client Supplied	**0.21**				mg/L			10/11/19 09:44	1
pH, Field	**7.19**				SU			10/11/19 09:44	1
Specific Conductance, Field	**1040**				umhos/cm			10/11/19 09:44	1
Temperature, Field	**13.73**				Degrees C			10/11/19 09:44	1
Turbidity, Field	**8.93**				NTU			10/11/19 09:44	1

Client Sample Results

Client: SCS Engineers
Job ID: 310-167314-1
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-310
Lab Sample ID: 310-167314-10
Date Collected: 10/11/19 08:02
Matrix: Water
Date Received: 10/12/19 09:45

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	59		5.0	1.5	mg/L			10/21/19 16:09	5
Fluoride	0.34	J	0.50	0.23	mg/L			10/21/19 16:09	5
Sulfate	51		5.0	1.8	mg/L			10/21/19 16:09	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 22:55	1
Arsenic	61		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 22:55	1
Barium	500		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 22:55	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/17/19 13:14	1
Boron	380		200	110	ug/L		10/15/19 07:39	10/17/19 13:14	1
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 22:55	1
Calcium	120		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 22:55	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 22:55	1
Cobalt	1.9		0.50	0.091	ug/L		10/15/19 07:39	10/16/19 22:55	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 22:55	1
Lithium	<2.7		10	2.7	ug/L		10/15/19 07:39	10/17/19 13:14	1
Molybdenum	6.0		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 22:55	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 22:55	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	410		60	48	mg/L			10/18/19 11:40	1
pH	7.2	HF	0.1	0.1	SU			10/12/19 11:38	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	-189.7				millivolts			10/11/19 08:02	1
Oxygen, Dissolved, Client Supplied	0.28				mg/L			10/11/19 08:02	1
pH, Field	6.95				SU			10/11/19 08:02	1
Specific Conductance, Field	961				umhos/cm			10/11/19 08:02	1
Temperature, Field	15.88				Degrees C			10/11/19 08:02	1
Turbidity, Field	5.23				NTU			10/11/19 08:02	1

Client Sample ID: MW-311
Date Collected: 10/11/19 08:54
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-11
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	65		5.0	1.5	mg/L			10/21/19 16:41	5
Fluoride	0.37	J	0.50	0.23	mg/L			10/21/19 16:41	5
Sulfate	130		5.0	1.8	mg/L			10/21/19 16:41	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 22:58	1
Arsenic	18		2.0	0.75	ug/L		10/15/19 07:39	10/17/19 13:16	1
Barium	210		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 22:58	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/17/19 13:16	1
Boron	2800		200	110	ug/L		10/15/19 07:39	10/17/19 13:16	1
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 22:58	1
Calcium	150		0.50	0.10	mg/L		10/15/19 07:39	10/17/19 13:16	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 22:58	1
Cobalt	0.27	J	0.50	0.091	ug/L		10/15/19 07:39	10/16/19 22:58	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 22:58	1
Lithium	<2.7		10	2.7	ug/L		10/15/19 07:39	10/17/19 13:16	1
Molybdenum	15		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 22:58	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 22:58	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	590		60	48	mg/L			10/18/19 11:40	1
pH	7.2	HF	0.1	0.1	SU			10/12/19 12:04	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	-163.4				millivolts			10/11/19 08:54	1
Oxygen, Dissolved, Client Supplied	0.30				mg/L			10/11/19 08:54	1
pH, Field	7.07				SU			10/11/19 08:54	1
Specific Conductance, Field	1088				umhos/cm			10/11/19 08:54	1
Temperature, Field	14.19				Degrees C			10/11/19 08:54	1
Turbidity, Field	13.4				NTU			10/11/19 08:54	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Client Sample ID: MW-312

Date Collected: 10/10/19 15:22
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-12
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	25		5.0	1.5	mg/L			10/21/19 16:56	5
Fluoride	0.25	J	0.50	0.23	mg/L			10/21/19 16:56	5
Sulfate	230		5.0	1.8	mg/L			10/21/19 16:56	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 23:05	1
Arsenic	15		4.0	1.5	ug/L		10/15/19 07:39	10/17/19 13:22	2
Barium	150		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 23:05	1
Beryllium	<0.54		2.0	0.54	ug/L		10/15/19 07:39	10/17/19 13:22	2
Boron	6600		400	220	ug/L		10/15/19 07:39	10/17/19 13:22	2
Cadmium	0.044	J	0.10	0.039	ug/L		10/15/19 07:39	10/16/19 23:05	1
Calcium	71		1.0	0.20	mg/L		10/15/19 07:39	10/17/19 13:22	2
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 23:05	1
Cobalt	0.36	J	0.50	0.091	ug/L		10/15/19 07:39	10/16/19 23:05	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 23:05	1
Lithium	27		20	5.4	ug/L		10/15/19 07:39	10/17/19 13:22	2
Molybdenum	280		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 23:05	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 23:05	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	510		150	120	mg/L			10/16/19 10:06	1
pH	7.3	HF	0.1	0.1	SU			10/12/19 12:06	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	-163.8				millivolts			10/10/19 15:22	1
Oxygen, Dissolved, Client Supplied	8.75				mg/L			10/10/19 15:22	1
pH, Field	7.19				SU			10/10/19 15:22	1
Specific Conductance, Field	785				umhos/cm			10/10/19 15:22	1
Temperature, Field	15.6				Degrees C			10/10/19 15:22	1
Turbidity, Field	2.56				NTU			10/10/19 15:22	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Client Sample ID: MW-313
Date Collected: 10/10/19 14:36
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-13
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	**51**		5.0	1.5	mg/L			10/21/19 17:12	5
Fluoride	**0.28**	**J**	0.50	0.23	mg/L			10/21/19 17:12	5
Sulfate	**210**		5.0	1.8	mg/L			10/21/19 17:12	5

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 23:09	1
Arsenic	**6.3**		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 23:09	1
Barium	**490**		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 23:09	1
Beryllium	<1.1		4.0	1.1	ug/L		10/15/19 07:39	10/17/19 13:24	4
Boron	**8500**		800	440	ug/L		10/15/19 07:39	10/17/19 13:24	4
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 23:09	1
Calcium	**120**		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 23:09	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 23:09	1
Cobalt	**0.32**	**J**	0.50	0.091	ug/L		10/15/19 07:39	10/16/19 23:09	1
Lead	**0.31**	**J**	0.50	0.27	ug/L		10/15/19 07:39	10/16/19 23:09	1
Lithium	**62**		40	11	ug/L		10/15/19 07:39	10/17/19 13:24	4
Molybdenum	**110**		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 23:09	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 23:09	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**520**		150	120	mg/L			10/16/19 10:06	1
pH	**7.2**	**HF**	0.1	0.1	SU			10/12/19 12:08	1

Method: Field Sampling - Field Sampling

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Oxidation Reduction Potential	**-163.4**				millivolts			10/10/19 14:36	1
Oxygen, Dissolved, Client Supplied	**0.37**				mg/L			10/10/19 14:36	1
pH, Field	**7.06**				SU			10/10/19 14:36	1
Specific Conductance, Field	**1007**				umhos/cm			10/10/19 14:36	1
Temperature, Field	**16.04**				Degrees C			10/10/19 14:36	1
Turbidity, Field	**11.03**				NTU			10/10/19 14:36	1

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Client Sample ID: Field Blank
Date Collected: 10/10/19 23:59
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-14
Matrix: Water

Method: 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	<0.29		1.0	0.29	mg/L			10/21/19 17:28	1
Fluoride	<0.045		0.10	0.045	mg/L			10/21/19 17:28	1
Sulfate	<0.35		1.0	0.35	mg/L			10/21/19 17:28	1

Method: 6020A - Metals (ICP/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 23:12	1
Arsenic	<0.75		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 23:12	1
Barium	<0.84		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 23:12	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/16/19 23:12	1
Boron	<110		200	110	ug/L		10/15/19 07:39	10/17/19 13:27	1
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 23:12	1
Calcium	<0.10		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 23:12	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 23:12	1
Cobalt	<0.091		0.50	0.091	ug/L		10/15/19 07:39	10/16/19 23:12	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 23:12	1
Lithium	<2.7		10	2.7	ug/L		10/15/19 07:39	10/16/19 23:12	1
Molybdenum	<1.1		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 23:12	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 23:12	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	<24		30	24	mg/L			10/16/19 10:06	1
pH	**5.7**	**HF**	0.1	0.1	SU			10/12/19 12:10	1

Definitions/Glossary

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Qualifiers

HPLC/IC

Qualifier	Qualifier Description
J	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

Metals

Qualifier	Qualifier Description
4	MS, MSD: The analyte present in the original sample is greater than 4 times the matrix spike concentration; therefore, control limits are not applicable.
J	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

General Chemistry

Qualifier	Qualifier Description
HF	Field parameter with a holding time of 15 minutes. Test performed by laboratory at client's request.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

QC Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Method: 9056A - Anions, Ion Chromatography

Lab Sample ID: MB 310-258109/3
Matrix: Water
Analysis Batch: 258109

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	<0.29		1.0	0.29	mg/L			10/21/19 09:13	1
Fluoride	<0.045		0.10	0.045	mg/L			10/21/19 09:13	1
Sulfate	<0.35		1.0	0.35	mg/L			10/21/19 09:13	1

Lab Sample ID: LCS 310-258109/4
Matrix: Water
Analysis Batch: 258109

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Chloride	10.0	9.87		mg/L		99	90 - 110
Fluoride	2.00	2.02		mg/L		101	90 - 110
Sulfate	10.0	10.0		mg/L		100	90 - 110

Method: 6020A - Metals (ICP/MS)

Lab Sample ID: MB 310-256797/1-A
Matrix: Water
Analysis Batch: 257130

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 256797

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.53		1.0	0.53	ug/L		10/15/19 07:39	10/16/19 21:43	1
Arsenic	<0.75		2.0	0.75	ug/L		10/15/19 07:39	10/16/19 21:43	1
Barium	<0.84		2.0	0.84	ug/L		10/15/19 07:39	10/16/19 21:43	1
Beryllium	<0.27		1.0	0.27	ug/L		10/15/19 07:39	10/16/19 21:43	1
Boron	<110		200	110	ug/L		10/15/19 07:39	10/16/19 21:43	1
Cadmium	<0.039		0.10	0.039	ug/L		10/15/19 07:39	10/16/19 21:43	1
Calcium	<0.10		0.50	0.10	mg/L		10/15/19 07:39	10/16/19 21:43	1
Chromium	<0.98		5.0	0.98	ug/L		10/15/19 07:39	10/16/19 21:43	1
Cobalt	<0.091		0.50	0.091	ug/L		10/15/19 07:39	10/16/19 21:43	1
Lead	<0.27		0.50	0.27	ug/L		10/15/19 07:39	10/16/19 21:43	1
Lithium	<2.7		10	2.7	ug/L		10/15/19 07:39	10/16/19 21:43	1
Molybdenum	<1.1		2.0	1.1	ug/L		10/15/19 07:39	10/16/19 21:43	1
Selenium	<1.0		5.0	1.0	ug/L		10/15/19 07:39	10/16/19 21:43	1

Lab Sample ID: LCS 310-256797/2-A
Matrix: Water
Analysis Batch: 257130

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 256797

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Antimony	40.0	34.1		ug/L		85	80 - 120
Arsenic	80.0	74.3		ug/L		93	80 - 120
Barium	80.0	80.5		ug/L		101	80 - 120
Beryllium	40.0	41.2		ug/L		103	80 - 120
Boron	1760	1600		ug/L		91	80 - 120
Cadmium	40.0	41.9		ug/L		105	80 - 120
Calcium	4.00	3.91		mg/L		98	80 - 120
Chromium	80.0	80.2		ug/L		100	80 - 120
Cobalt	40.0	40.8		ug/L		102	80 - 120
Lead	40.0	40.7		ug/L		102	80 - 120

Eurofins TestAmerica, Cedar Falls

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Method: 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: LCS 310-256797/2-A
Matrix: Water
Analysis Batch: 257130

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 256797

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits		
Lithium			200	193		ug/L		96	80 - 120		
Molybdenum			80.0	73.8		ug/L		92	80 - 120		
Selenium			80.0	73.3		ug/L		92	80 - 120		

Lab Sample ID: 310-167314-1 MS
Matrix: Water
Analysis Batch: 257130

Client Sample ID: MW-301
Prep Type: Total/NA
Prep Batch: 256797

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits		
Antimony	<0.53		40.0	37.8		ug/L		94	75 - 125		
Arsenic	40		80.0	117		ug/L		96	75 - 125		
Barium	320		80.0	383		ug/L		85	75 - 125		
Beryllium	<0.27		40.0	39.5		ug/L		99	75 - 125		
Cadmium	<0.039		40.0	40.6		ug/L		102	75 - 125		
Calcium	130		4.00	126	4	mg/L		-9	75 - 125		
Chromium	<0.98		80.0	77.4		ug/L		97	75 - 125		
Cobalt	0.18	J	40.0	39.0		ug/L		97	75 - 125		
Lead	<0.27		40.0	39.9		ug/L		100	75 - 125		
Lithium	26		200	211		ug/L		93	75 - 125		
Molybdenum	130		80.0	204		ug/L		96	75 - 125		
Selenium	<1.0		80.0	75.0		ug/L		94	75 - 125		

Lab Sample ID: 310-167314-1 MS
Matrix: Water
Analysis Batch: 257278

Client Sample ID: MW-301
Prep Type: Total/NA
Prep Batch: 256797

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits		
Boron	8100		1760	9420	4	ug/L		76	75 - 125		

Lab Sample ID: 310-167314-1 MSD
Matrix: Water
Analysis Batch: 257130

Client Sample ID: MW-301
Prep Type: Total/NA
Prep Batch: 256797

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Antimony	<0.53		40.0	38.1		ug/L		95	75 - 125	1	20
Arsenic	40		80.0	118		ug/L		98	75 - 125	1	20
Barium	320		80.0	389		ug/L		92	75 - 125	2	20
Beryllium	<0.27		40.0	40.7		ug/L		102	75 - 125	3	20
Cadmium	<0.039		40.0	41.9		ug/L		105	75 - 125	3	20
Calcium	130		4.00	128	4	mg/L		30	75 - 125	1	20
Chromium	<0.98		80.0	78.9		ug/L		99	75 - 125	2	20
Cobalt	0.18	J	40.0	39.4		ug/L		98	75 - 125	1	20
Lead	<0.27		40.0	40.8		ug/L		102	75 - 125	2	20
Lithium	26		200	217		ug/L		95	75 - 125	2	20
Molybdenum	130		80.0	208		ug/L		101	75 - 125	2	20
Selenium	<1.0		80.0	75.0		ug/L		94	75 - 125	0	20

Method: 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: 310-167314-1 MSD **Client Sample ID: MW-301**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 257278 **Prep Batch: 256797**

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Boron	8100		1760	9960	4	ug/L		107	75 - 125	6	20

Lab Sample ID: 310-167314-11 DU **Client Sample ID: MW-311**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 257130 **Prep Batch: 256797**

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Antimony	<0.53		<0.53		ug/L		NC	20
Barium	210		213		ug/L		0.6	20
Cadmium	<0.039		<0.039		ug/L		NC	20
Chromium	<0.98		<0.98		ug/L		NC	20
Cobalt	0.27	J	0.274	J	ug/L		0.7	20
Lead	<0.27		<0.27		ug/L		NC	20
Molybdenum	15		14.8		ug/L		0	20
Selenium	<1.0		<1.0		ug/L		NC	20

Lab Sample ID: 310-167314-11 DU **Client Sample ID: MW-311**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 257278 **Prep Batch: 256797**

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Arsenic	18		19.2		ug/L		5	20
Beryllium	<0.27		<0.27		ug/L		NC	20
Boron	2800		2920		ug/L		5	20
Calcium	150		155		mg/L		4	20
Lithium	<2.7		<2.7		ug/L		NC	20

Method: SM 2540C - Solids, Total Dissolved (TDS)

Lab Sample ID: MB 310-257014/1 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 257014

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	<24		30	24	mg/L			10/16/19 10:06	1

Lab Sample ID: LCS 310-257014/2 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 257014

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Total Dissolved Solids	1000	994		mg/L		99	90 - 110

Lab Sample ID: 310-167314-1 DU **Client Sample ID: MW-301**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 257014

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Total Dissolved Solids	690		700		mg/L		1	24

Method: SM 2540C - Solids, Total Dissolved (TDS) (Continued)

Lab Sample ID: MB 310-257410/1
Matrix: Water
Analysis Batch: 257410

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	<24		30	24	mg/L			10/18/19 11:40	1

Lab Sample ID: LCS 310-257410/2
Matrix: Water
Analysis Batch: 257410

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Total Dissolved Solids	1000	964		mg/L		96	90 - 110

Method: SM 4500 H+ B - pH

Lab Sample ID: LCS 310-256487/1
Matrix: Water
Analysis Batch: 256487

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
pH	7.00	7.0		SU		100	98 - 102

Lab Sample ID: 310-167314-1 DU
Matrix: Water
Analysis Batch: 256487

Client Sample ID: MW-301
Prep Type: Total/NA

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
pH	7.1	HF	7.1		SU		0	20

Lab Sample ID: 310-167314-10 DU
Matrix: Water
Analysis Batch: 256487

Client Sample ID: MW-310
Prep Type: Total/NA

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
pH	7.2	HF	7.2		SU		0	20

QC Association Summary

Client: SCS Engineers | Job ID: 310-167314-1
Project/Site: Burlington Gen Station 25216066

HPLC/IC

Analysis Batch: 258109

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-1	MW-301	Total/NA	Water	9056A	
310-167314-1	MW-301	Total/NA	Water	9056A	
310-167314-2	MW-302	Total/NA	Water	9056A	
310-167314-2	MW-302	Total/NA	Water	9056A	
310-167314-3	MW-303	Total/NA	Water	9056A	
310-167314-4	MW-304	Total/NA	Water	9056A	
310-167314-5	MW-305	Total/NA	Water	9056A	
310-167314-6	MW-306	Total/NA	Water	9056A	
310-167314-7	MW-307	Total/NA	Water	9056A	
310-167314-8	MW-308	Total/NA	Water	9056A	
310-167314-9	MW-309	Total/NA	Water	9056A	
310-167314-10	MW-310	Total/NA	Water	9056A	
310-167314-11	MW-311	Total/NA	Water	9056A	
310-167314-12	MW-312	Total/NA	Water	9056A	
310-167314-13	MW-313	Total/NA	Water	9056A	
310-167314-14	Field Blank	Total/NA	Water	9056A	
MB 310-258109/3	Method Blank	Total/NA	Water	9056A	
LCS 310-258109/4	Lab Control Sample	Total/NA	Water	9056A	

Metals

Prep Batch: 256797

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-1	MW-301	Total/NA	Water	3010A	
310-167314-2	MW-302	Total/NA	Water	3010A	
310-167314-3	MW-303	Total/NA	Water	3010A	
310-167314-4	MW-304	Total/NA	Water	3010A	
310-167314-5	MW-305	Total/NA	Water	3010A	
310-167314-6	MW-306	Total/NA	Water	3010A	
310-167314-7	MW-307	Total/NA	Water	3010A	
310-167314-8	MW-308	Total/NA	Water	3010A	
310-167314-9	MW-309	Total/NA	Water	3010A	
310-167314-10	MW-310	Total/NA	Water	3010A	
310-167314-11	MW-311	Total/NA	Water	3010A	
310-167314-12	MW-312	Total/NA	Water	3010A	
310-167314-13	MW-313	Total/NA	Water	3010A	
310-167314-14	Field Blank	Total/NA	Water	3010A	
MB 310-256797/1-A	Method Blank	Total/NA	Water	3010A	
LCS 310-256797/2-A	Lab Control Sample	Total/NA	Water	3010A	
310-167314-1 MS	MW-301	Total/NA	Water	3010A	
310-167314-1 MSD	MW-301	Total/NA	Water	3010A	
310-167314-11 DU	MW-311	Total/NA	Water	3010A	

Analysis Batch: 257130

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-1	MW-301	Total/NA	Water	6020A	256797
310-167314-2	MW-302	Total/NA	Water	6020A	256797
310-167314-3	MW-303	Total/NA	Water	6020A	256797
310-167314-4	MW-304	Total/NA	Water	6020A	256797
310-167314-5	MW-305	Total/NA	Water	6020A	256797
310-167314-6	MW-306	Total/NA	Water	6020A	256797

Metals (Continued)

Analysis Batch: 257130 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-7	MW-307	Total/NA	Water	6020A	256797
310-167314-8	MW-308	Total/NA	Water	6020A	256797
310-167314-9	MW-309	Total/NA	Water	6020A	256797
310-167314-10	MW-310	Total/NA	Water	6020A	256797
310-167314-11	MW-311	Total/NA	Water	6020A	256797
310-167314-12	MW-312	Total/NA	Water	6020A	256797
310-167314-13	MW-313	Total/NA	Water	6020A	256797
310-167314-14	Field Blank	Total/NA	Water	6020A	256797
MB 310-256797/1-A	Method Blank	Total/NA	Water	6020A	256797
LCS 310-256797/2-A	Lab Control Sample	Total/NA	Water	6020A	256797
310-167314-1 MS	MW-301	Total/NA	Water	6020A	256797
310-167314-1 MSD	MW-301	Total/NA	Water	6020A	256797
310-167314-11 DU	MW-311	Total/NA	Water	6020A	256797

Analysis Batch: 257278

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-1	MW-301	Total/NA	Water	6020A	256797
310-167314-2	MW-302	Total/NA	Water	6020A	256797
310-167314-3	MW-303	Total/NA	Water	6020A	256797
310-167314-4	MW-304	Total/NA	Water	6020A	256797
310-167314-5	MW-305	Total/NA	Water	6020A	256797
310-167314-6	MW-306	Total/NA	Water	6020A	256797
310-167314-7	MW-307	Total/NA	Water	6020A	256797
310-167314-8	MW-308	Total/NA	Water	6020A	256797
310-167314-9	MW-309	Total/NA	Water	6020A	256797
310-167314-10	MW-310	Total/NA	Water	6020A	256797
310-167314-11	MW-311	Total/NA	Water	6020A	256797
310-167314-12	MW-312	Total/NA	Water	6020A	256797
310-167314-13	MW-313	Total/NA	Water	6020A	256797
310-167314-14	Field Blank	Total/NA	Water	6020A	256797
310-167314-1 MS	MW-301	Total/NA	Water	6020A	256797
310-167314-1 MSD	MW-301	Total/NA	Water	6020A	256797
310-167314-11 DU	MW-311	Total/NA	Water	6020A	256797

General Chemistry

Analysis Batch: 256487

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-1	MW-301	Total/NA	Water	SM 4500 H+ B	
310-167314-2	MW-302	Total/NA	Water	SM 4500 H+ B	
310-167314-3	MW-303	Total/NA	Water	SM 4500 H+ B	
310-167314-4	MW-304	Total/NA	Water	SM 4500 H+ B	
310-167314-5	MW-305	Total/NA	Water	SM 4500 H+ B	
310-167314-6	MW-306	Total/NA	Water	SM 4500 H+ B	
310-167314-7	MW-307	Total/NA	Water	SM 4500 H+ B	
310-167314-8	MW-308	Total/NA	Water	SM 4500 H+ B	
310-167314-9	MW-309	Total/NA	Water	SM 4500 H+ B	
310-167314-10	MW-310	Total/NA	Water	SM 4500 H+ B	
310-167314-11	MW-311	Total/NA	Water	SM 4500 H+ B	
310-167314-12	MW-312	Total/NA	Water	SM 4500 H+ B	
310-167314-13	MW-313	Total/NA	Water	SM 4500 H+ B	

General Chemistry (Continued)

Analysis Batch: 256487 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-14	Field Blank	Total/NA	Water	SM 4500 H+ B	
LCS 310-256487/1	Lab Control Sample	Total/NA	Water	SM 4500 H+ B	
310-167314-1 DU	MW-301	Total/NA	Water	SM 4500 H+ B	
310-167314-10 DU	MW-310	Total/NA	Water	SM 4500 H+ B	

Analysis Batch: 257014

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-1	MW-301	Total/NA	Water	SM 2540C	
310-167314-2	MW-302	Total/NA	Water	SM 2540C	
310-167314-3	MW-303	Total/NA	Water	SM 2540C	
310-167314-4	MW-304	Total/NA	Water	SM 2540C	
310-167314-5	MW-305	Total/NA	Water	SM 2540C	
310-167314-8	MW-308	Total/NA	Water	SM 2540C	
310-167314-12	MW-312	Total/NA	Water	SM 2540C	
310-167314-13	MW-313	Total/NA	Water	SM 2540C	
310-167314-14	Field Blank	Total/NA	Water	SM 2540C	
MB 310-257014/1	Method Blank	Total/NA	Water	SM 2540C	
LCS 310-257014/2	Lab Control Sample	Total/NA	Water	SM 2540C	
310-167314-1 DU	MW-301	Total/NA	Water	SM 2540C	

Analysis Batch: 257410

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-6	MW-306	Total/NA	Water	SM 2540C	
310-167314-7	MW-307	Total/NA	Water	SM 2540C	
310-167314-9	MW-309	Total/NA	Water	SM 2540C	
310-167314-10	MW-310	Total/NA	Water	SM 2540C	
310-167314-11	MW-311	Total/NA	Water	SM 2540C	
MB 310-257410/1	Method Blank	Total/NA	Water	SM 2540C	
LCS 310-257410/2	Lab Control Sample	Total/NA	Water	SM 2540C	

Field Service / Mobile Lab

Analysis Batch: 257065

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-1	MW-301	Total/NA	Water	Field Sampling	
310-167314-2	MW-302	Total/NA	Water	Field Sampling	
310-167314-3	MW-303	Total/NA	Water	Field Sampling	
310-167314-4	MW-304	Total/NA	Water	Field Sampling	
310-167314-5	MW-305	Total/NA	Water	Field Sampling	
310-167314-6	MW-306	Total/NA	Water	Field Sampling	
310-167314-7	MW-307	Total/NA	Water	Field Sampling	
310-167314-8	MW-308	Total/NA	Water	Field Sampling	
310-167314-9	MW-309	Total/NA	Water	Field Sampling	
310-167314-10	MW-310	Total/NA	Water	Field Sampling	
310-167314-11	MW-311	Total/NA	Water	Field Sampling	
310-167314-12	MW-312	Total/NA	Water	Field Sampling	
310-167314-13	MW-313	Total/NA	Water	Field Sampling	

Lab Chronicle

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Client Sample ID: MW-301
Date Collected: 10/10/19 11:02
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-1
Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 12:20	CJT	TAL CF
Total/NA	Analysis	9056A		20	258109	10/21/19 17:43	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 21:50	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		4	257278	10/17/19 12:37	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257014	10/16/19 10:06	LBB	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 12:01	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/10/19 11:02	EAR	TAL CF

Client Sample ID: MW-302
Date Collected: 10/10/19 12:12
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-2
Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 12:35	CJT	TAL CF
Total/NA	Analysis	9056A		20	258109	10/21/19 17:59	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 22:17	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		4	257278	10/17/19 12:45	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257014	10/16/19 10:06	LBB	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 11:55	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/10/19 12:12	EAR	TAL CF

Client Sample ID: MW-303
Date Collected: 10/10/19 13:00
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-3
Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 12:51	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 22:21	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		10	257278	10/17/19 12:47	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257014	10/16/19 10:06	LBB	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 11:53	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/10/19 13:00	EAR	TAL CF

Lab Chronicle

Client: SCS Engineers | Job ID: 310-167314-1
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-304
Lab Sample ID: 310-167314-4
Date Collected: 10/10/19 13:44
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 13:06	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 22:24	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		4	257278	10/17/19 12:50	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257014	10/16/19 10:06	LBB	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 11:51	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/10/19 13:44	EAR	TAL CF

Client Sample ID: MW-305
Lab Sample ID: 310-167314-5
Date Collected: 10/11/19 10:30
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 13:22	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 22:28	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		2	257278	10/17/19 12:53	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257014	10/16/19 10:06	LBB	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 11:49	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/11/19 10:30	EAR	TAL CF

Client Sample ID: MW-306
Lab Sample ID: 310-167314-6
Date Collected: 10/11/19 11:16
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 13:38	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 22:31	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		2	257278	10/17/19 12:55	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257410	10/18/19 11:40	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 11:48	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/11/19 11:16	EAR	TAL CF

Client Sample ID: MW-307
Lab Sample ID: 310-167314-7
Date Collected: 10/11/19 15:06
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 14:09	CJT	TAL CF

Client Sample ID: MW-307
Lab Sample ID: 310-167314-7
Date Collected: 10/11/19 15:06
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 22:34	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		2	257278	10/17/19 12:58	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257410	10/18/19 11:40	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 11:46	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/11/19 15:06	EAR	TAL CF

Client Sample ID: MW-308
Lab Sample ID: 310-167314-8
Date Collected: 10/10/19 10:08
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 14:24	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 22:48	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		2	257278	10/17/19 13:01	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257014	10/16/19 10:06	LBB	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 11:44	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/10/19 10:08	EAR	TAL CF

Client Sample ID: MW-309
Lab Sample ID: 310-167314-9
Date Collected: 10/11/19 09:44
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 14:40	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 22:52	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		2	257278	10/17/19 13:11	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257410	10/18/19 11:40	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 11:42	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/11/19 09:44	EAR	TAL CF

Client Sample ID: MW-310
Lab Sample ID: 310-167314-10
Date Collected: 10/11/19 08:02
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 16:09	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 22:55	SAD	TAL CF

Lab Chronicle

Client: SCS Engineers — Job ID: 310-167314-1
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-310 — Lab Sample ID: 310-167314-10

Date Collected: 10/11/19 08:02 — **Matrix: Water**
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257278	10/17/19 13:14	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257410	10/18/19 11:40	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 11:38	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/11/19 08:02	EAR	TAL CF

Client Sample ID: MW-311 — Lab Sample ID: 310-167314-11

Date Collected: 10/11/19 08:54 — **Matrix: Water**
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 16:41	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 22:58	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257278	10/17/19 13:16	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257410	10/18/19 11:40	MDK	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 12:04	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/11/19 08:54	EAR	TAL CF

Client Sample ID: MW-312 — Lab Sample ID: 310-167314-12

Date Collected: 10/10/19 15:22 — **Matrix: Water**
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 16:56	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 23:05	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		2	257278	10/17/19 13:22	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257014	10/16/19 10:06	LBB	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 12:06	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/10/19 15:22	EAR	TAL CF

Client Sample ID: MW-313 — Lab Sample ID: 310-167314-13

Date Collected: 10/10/19 14:36 — **Matrix: Water**
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		5	258109	10/21/19 17:12	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 23:09	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		4	257278	10/17/19 13:24	SAD	TAL CF

Client Sample ID: MW-313

Lab Sample ID: 310-167314-13

Date Collected: 10/10/19 14:36
Date Received: 10/12/19 09:45

Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	SM 2540C		1	257014	10/16/19 10:06	LBB	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 12:08	SAS	TAL CF
Total/NA	Analysis	Field Sampling		1	257065	10/10/19 14:36	EAR	TAL CF

Client Sample ID: Field Blank

Lab Sample ID: 310-167314-14

Date Collected: 10/10/19 23:59
Date Received: 10/12/19 09:45

Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	9056A		1	258109	10/21/19 17:28	CJT	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257130	10/16/19 23:12	SAD	TAL CF
Total/NA	Prep	3010A			256797	10/15/19 07:39	HED	TAL CF
Total/NA	Analysis	6020A		1	257278	10/17/19 13:27	SAD	TAL CF
Total/NA	Analysis	SM 2540C		1	257014	10/16/19 10:06	LBB	TAL CF
Total/NA	Analysis	SM 4500 H+ B		1	256487	10/12/19 12:10	SAS	TAL CF

Laboratory References:

TAL CF = Eurofins TestAmerica, Cedar Falls, 3019 Venture Way, Cedar Falls, IA 50613, TEL (319)277-2401

Accreditation/Certification Summary

Client: SCS Engineers
Job ID: 310-167314-1
Project/Site: Burlington Gen Station 25216066

Laboratory: Eurofins TestAmerica, Cedar Falls

The accreditations/certifications listed below are applicable to this report.

Authority	Program	Identification Number	Expiration Date
Iowa	State Program	007	12-01-19

Method Summary

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-1

Method	Method Description	Protocol	Laboratory
9056A	Anions, Ion Chromatography	SW846	TAL CF
6020A	Metals (ICP/MS)	SW846	TAL CF
SM 2540C	Solids, Total Dissolved (TDS)	SM	TAL CF
SM 4500 H+ B	pH	SM	TAL CF
Field Sampling	Field Sampling	EPA	TAL CF
3010A	Preparation, Total Metals	SW846	TAL CF

Protocol References:

EPA = US Environmental Protection Agency

SM = "Standard Methods For The Examination Of Water And Wastewater"

SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

Laboratory References:

TAL CF = Eurofins TestAmerica, Cedar Falls, 3019 Venture Way, Cedar Falls, IA 50613, TEL (319)277-2401

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310-167314 Chain of Custody

Cooler/Sample Receipt and Temperature Log Form

Client Information

Client: SCS Engineers

City/State: CITY Clive STATE IA | Project: Burlington Gen Station

Receipt Information

Date/Time Received: DATE 10-12-19 TIME 945 | Received By: LAB

Delivery Type: ☐ UPS ☒ FedEx sat ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee ☐ Lab Courier ☐ Lab Field Services ☐ Client Drop-off ☐ Other:________

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes ☐ No	*If yes:* Cooler ID:	
Multiple Coolers?	☒ Yes ☐ No	*If yes:* Cooler # 1 of 3	
Cooler Custody Seals Present?	☒ Yes ☐ No	*If yes:* Cooler custody seals intact?	☐ Yes ☐ No
Sample Custody Seals Present?	☐ Yes ☒ No	*If yes:* Sample custody seals intact?	☐ Yes ☐ No
Trip Blank Present?	☐ Yes ☒ No	*If yes:* Which VOA samples are in cooler? ↓	

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:________ ☐ NONE

Thermometer ID: N | Correction Factor (°C): +0.0

• Temp Blank Temperature – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): 0.5 | Corrected Temp (°C): 0.5

• Sample Container Temperature

	CONTAINER 1	CONTAINER 2
Container(s) used:		
Uncorrected Temp (°C):		
Corrected Temp (°C):		

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

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Place COC scanning label here

Cooler/Sample Receipt and Temperature Log Form

Client Information

Client: SCS Engineers

City/State: CITY Clive STATE IA | Project: Burlington Gen Station

Receipt Information

Date/Time Received: DATE 10-12-19 TIME 945 | Received By: LAB

Delivery Type: ☐ UPS ☒ FedEx sat ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee
☐ Lab Courier ☐ Lab Field Services ☐ Client Drop-off ☐ Other:____________

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes	☐ No	*If yes:* Cooler ID:
Multiple Coolers?	☒ Yes	☐ No	*If yes:* Cooler # 2 of 3
Cooler Custody Seals Present?	☒ Yes	☐ No	*If yes:* Cooler custody seals intact? ☐ Yes ☐ No
Sample Custody Seals Present?	☐ Yes	☒ No	*If yes:* Sample custody seals intact? ☐ Yes ☐ No
Trip Blank Present?	☐ Yes	☒ No	*If yes:* Which VOA samples are in cooler? ↓

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:____________ ☐ NONE

Thermometer ID: N | Correction Factor (°C): +0.0

• Temp Blank Temperature – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): 0.1 | Corrected Temp (°C): 0.1

• Sample Container Temperature

	CONTAINER 1	CONTAINER 2
Container(s) used:		
Uncorrected Temp (°C):		
Corrected Temp (°C):		

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

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Place COC scanning label here

Cooler/Sample Receipt and Temperature Log Form

Client Information			
Client: SCS Engineers			
City/State: CITY Clive	STATE IA	Project: Burlington Gen Station	
Receipt Information			
Date/Time Received: DATE 10-12-19	TIME 945	Received By: LAB	

Delivery Type: ☐ UPS ☒ FedEx sat ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee ☐ Lab Courier ☐ Lab Field Services ☐ Client Drop-off ☐ Other:________

Condition of Cooler/Containers			
Sample(s) received in Cooler?	☒ Yes	☐ No	*If yes:* Cooler ID:
Multiple Coolers?	☒ Yes	☐ No	*If yes:* Cooler # 3 of 3
Cooler Custody Seals Present?	☒ Yes	☐ No	*If yes:* Cooler custody seals intact? ☐ Yes ☐ No
Sample Custody Seals Present?	☐ Yes	☒ No	*If yes:* Sample custody seals intact? ☐ Yes ☐ No
Trip Blank Present?	☐ Yes	☒ No	*If yes:* Which VOA samples are in cooler? ↓

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:________ ☐ NONE

Thermometer ID: N	Correction Factor (°C): +0.0

• Temp Blank Temperature – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): 1.3	Corrected Temp (°C): 1.3

• Sample Container Temperature

	CONTAINER 1	CONTAINER 2
Container(s) used:		
Uncorrected Temp (°C):		
Corrected Temp (°C):		

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

Document: CF-LG-WI-002
Revision: 25
Date: 06/17/2019

Eurofins TestAmerica, Cedar Falls

General temperature criteria is 0 to 6°C
Bacteria temperature criteria is 0 to 10°C

Table 1. Sampling Points and Parameters - CCR Rule Sampling Program Assessment Monitoring Groundwater Monitoring - Burlington Generating Station / SCS Engineers Project #25216066

	Parameter	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306	MW-307	MW-308	MW-309	MW-310	MW-311	MW-312	MW-313	Field Blank	TOTAL
Appendix III Parameters	Boron	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Calcium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Chloride	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Fluoride	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	pH	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Sulfate	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	TDS	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
Appendix IV Parameters	Antimony	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Arsenic	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Barium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Beryllium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Cadmium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Chromium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Cobalt	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Fluoride	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Lead	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Lithium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Mercury															0
	Molybdenum	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Selenium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Thallium															0
	Radium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
Field Parameters	Groundwater Elevation	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Well Depth	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	pH (field)	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Specific Conductance	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Dissolved Oxygen	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	ORP	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Temperature	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Turbidity	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Color	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Odor	x	x	x	x	x	x	x	x	x	x	x	x	x		13

Notes: All samples are unfiltered (total).

I:\25219066.00\Data and Calculations\Field Work Requests\[Table_1_BGS_CCR_Rule_Sampling_1910.xls]Sheet1

Eurofins TestAmerica, Cedar Falls
3019 Venture Way
Cedar Falls, IA 50613
Phone: 319-277-2401 Fax: 319-277-2425

Chain of Custody Record

TestAmerica Des Moines SC
214

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43667

Client Information	Sampler: Louise Jennings	Lab PM: Fredrick, Sandie	Carrier Tracking No(s):	COC No: 310-43667-14046.1
Client Contact: Louise Jennings	Phone: 608 509 8245	E-Mail: sandie.fredrick@testamericainc.com		Page: Page 1 of 2
Company: SCS Engineers		Analysis Requested		Job #:
Address: 8450 Hickman Road Suite 20	Due Date Requested:			
City: Clive	TAT Requested (days): Standard			
State, Zip: IA, 50325				
Phone:	PO #: 25216066			
Email: ljennings@scsengineers.com	WO #:			
Project Name: Burlington Gen Station 25216066	Project #: 31011020			
Site:	SSOW#:			

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA
M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
Other:

Sample Identification	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	6020A - Metals - Hg	2540C_Calcd, 9056A_ORGFM_28D, SM4500_H+	903.0 - Radium 226	904.0 - Radium 228	Total Number of containers	Special Instructions/Note:
				Preservation Code:			D	N	D	D		
MW-301	10.10.19	1102	G	Water			X	X	X	X		
MW-302	10.10.19	1212	G	Water			X	X	X	X		
MW-303	10/10/19	1300	G	Water			X	X	X	X		
MW-304	10.10.19	1344	G	Water			X	X	X	X		
MW-305	10.11.19	1030	G	Water			X	X	X	X		
MW-306	10.11.19	1110	G	Water			X	X	X	X		
MW-307	10.11.19	1206	G	Water			X	X	X	X		
MW-308	10.10.19	1008	G	Water			X	X	X	X		
MW-309	10.11.19	0944	G	Water			X	X	X	X		
MW-310	10.11.19	0802	G	Water			X	X	X	X		
MW-311	10.11.19	0854	G	Water			X	X	X	X		

Possible Hazard Identification
☐ *Non-Hazard* ☐ *Flammable* ☐ *Skin Irritant* ☐ *Poison B* ☐ *Unknown* ☐ *Radiological*

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For ______ Months*

Deliverable Requested: I, II, III, IV, Other (specify)

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:		
Relinquished by: L Jennings	Date/Time: 10.11.19 16:15	Company: SCS	Received by: Lindsay Binder	Date/Time: 10-12-19 945	Company: ETA
Relinquished by:	Date/Time:	Company:	Received by:	Date/Time:	Company:
Relinquished by:	Date/Time:	Company:	Received by:	Date/Time:	Company:

Custody Seals Intact: Δ Yes Δ No | Custody Seal No.: | Cooler Temperature(s) °C and Other Remarks:

10/28/2019

15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Eurofins TestAmerica, Cedar Falls
3019 Venture Way
Cedar Falls, IA 50613
Phone (319) 277-2401 Fax (319) 277-2425

Chain of Custody Record

TestAmerica Des Moines SC
214

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43467

Client Information	Sampler: Louise Jennings	Lab PM: Fredrick, Sandie	Carrier Tracking No(s):	COC No: 310-43667-14046.2
Client Contact: Louise Jennings	Phone: 608 509 8845	E-Mail: sandie.fredrick@testamericainc.com		Page: Page 2 of 2
Company: SCS Engineers				Job #:
Address: 8450 Hickman Road Suite 20	Due Date Requested:			
City: Clive	TAT Requested (days): Standard			
State, Zip: IA, 50325				
Phone:	PO #: 25216066			
Email: ljennings@scsengineers.com	WO #:			
Project Name: Burlington Gen Station 25216066	Project #: 31011020			
Site:	SSOW#:			

Analysis Requested

Preservation Codes:

A - HCL	M - Hexane
B - NaOH	N - None
C - Zn Acetate	O - AsNaO2
D - Nitric Acid	P - Na2O4S
E - NaHSO4	Q - Na2SO3
F - MeOH	R - Na2S2O3
G - Amchlor	S - H2SO4
H - Ascorbic Acid	T - TSP Dodecahydrate
I - Ice	U - Acetone
J - DI Water	V - MCAA
K - EDTA	W - pH 4-5
L - EDA	Z - other (specify)

Other:

Sample Identification	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	6020A - Metals - Hg	2540C_Calcd, 9056A_ORGFM_28D, SM4500_H+	903.0 - Radium 226	904.0 - Radium 228	Total Number of containers	Special Instructions/Note:
				Preservation Code:	X	X	D	N	D	D	X	
MW-312	10.10.19	1522	G	Water								
MW-313	10.10.19	1436	G	Water								
Field Blank	10.10.19	2359	—	Water								
				Water								

Possible Hazard Identification
☐ *Non-Hazard* ☐ *Flammable* ☐ *Skin Irritant* ☐ *Poison B* ☐ *Unknown* ☐ *Radiological*

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* ______ *Months*

Deliverable Requested: I, II, III, IV, Other (specify)

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:

Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
L. Jennings	10.11.19 1615		Lindsay Burdett	10-12-19 945	ETA

Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:	Cooler Temperature(s) °C and Other Remarks:

10/28/2019

15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Login Container Summary Report

Temperature readings: ___

Client Sample ID	Lab ID	Container Type	Container pH	Preservative Added (mls)	Lot #
MW-301	310-167314-A-1	Plastic 250ml - with Nitric Acid	<2		
MW-301	310-167314-B-1	Plastic 1 liter - Nitric Acid	<2		
MW-301	310-167314-C-1	Plastic 1 liter - Nitric Acid	<2		
MW-302	310-167314-A-2	Plastic 250ml - with Nitric Acid	<2		
MW-302	310-167314-B-2	Plastic 1 liter - Nitric Acid	<2		
MW-302	310-167314-C-2	Plastic 1 liter - Nitric Acid	<2		
MW-303	310-167314-A-3	Plastic 250ml - with Nitric Acid	<2		
MW-303	310-167314-B-3	Plastic 1 liter - Nitric Acid	<2		
MW-303	310-167314-C-3	Plastic 1 liter - Nitric Acid	<2		
MW-304	310-167314-A-4	Plastic 250ml - with Nitric Acid	<2		
MW-304	310-167314-B-4	Plastic 1 liter - Nitric Acid	<2		
MW-304	310-167314-C-4	Plastic 1 liter - Nitric Acid	<2		
MW-305	310-167314-A-5	Plastic 250ml - with Nitric Acid	<2		
MW-305	310-167314-B-5	Plastic 1 liter - Nitric Acid	<2		
MW-305	310-167314-C-5	Plastic 1 liter - Nitric Acid	<2		
MW-306	310-167314-A-6	Plastic 250ml - with Nitric Acid	<2		
MW-306	310-167314-B-6	Plastic 1 liter - Nitric Acid	<2		
MW-306	310-167314-C-6	Plastic 1 liter - Nitric Acid	<2		
MW-307	310-167314-A-7	Plastic 250ml - with Nitric Acid	<2		
MW-307	310-167314-B-7	Plastic 1 liter - Nitric Acid	<2		
MW-307	310-167314-C-7	Plastic 1 liter - Nitric Acid	<2		
MW-308	310-167314-A-8	Plastic 250ml - with Nitric Acid	<2		
MW-308	310-167314-B-8	Plastic 1 liter - Nitric Acid	<2		
MW-308	310-167314-C-8	Plastic 1 liter - Nitric Acid	<2		
MW-309	310-167314-A-9	Plastic 250ml - with Nitric Acid	<2		
MW-309	310-167314-B-9	Plastic 1 liter - Nitric Acid	<2		
MW-309	310-167314-C-9	Plastic 1 liter - Nitric Acid	<2		
MW-310	310-167314-A-10	Plastic 250ml - with Nitric Acid	<2		
MW-310	310-167314-B-10	Plastic 1 liter - Nitric Acid	<2		
MW-310	310-167314-C-10	Plastic 1 liter - Nitric Acid	<2		
MW-311	310-167314-A-11	Plastic 250ml - with Nitric Acid	<2		
MW-311	310-167314-B-11	Plastic 1 liter - Nitric Acid	<2		
MW-311	310-167314-C-11	Plastic 1 liter - Nitric Acid	<2		
MW-312	310-167314-A-12	Plastic 250ml - with Nitric Acid	<2		
MW-312	310-167314-B-12	Plastic 1 liter - Nitric Acid	<2		
MW-312	310-167314-C-12	Plastic 1 liter - Nitric Acid	<2		
MW-313	310-167314-A-13	Plastic 250ml - with Nitric Acid	<2		

Client Sample ID	Lab ID	Container Type	Container pH	Preservative Added (mls)	Lot #
MW-313	310-167314-B-13	Plastic 1 liter - Nitric Acid	<2		
MW-313	310-167314-C-13	Plastic 1 liter - Nitric Acid	<2		
Field Blank	310-167314-A-14	Plastic 250ml - with Nitric Acid	<2		
Field Blank	310-167314-B-14	Plastic 1 liter - Nitric Acid	<2		
Field Blank	310-167314-C-14	Plastic 1 liter - Nitric Acid	<2		

Login Sample Receipt Checklist

Client: SCS Engineers

Job Number: 310-167314-1
SDG Number:

Login Number: 167314
List Number: 1
Creator: Homolar, Dana J

List Source: Eurofins TestAmerica, Cedar Falls

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Table 1. Groundwater Monitoring Results - Field Parameters
Burlington Generating Station / SCS Engineers Project No. 25219066
October 2019

Sample	Sample Date/Time	Temperature (Deg. C)	pH (Std. Units)	Dissolved Oxygen (mg/L)	Specific Conductivity (µmhos/cm)	ORP (mV)	Turbidity
MW-301	10.10.19/1102	13.9	6.85	0.23	1,063	-162.9	12.55
MW-302	10.10.19/1212	14.46	7.49	0.28	1,249	-186.8	1.16
MW-303	10.10.19/1300	14.91	7.13	0.26	767	-161.0	5.36
MW-304	10.10.19/1344	15.64	7.17	0.28	934	-157.5	1.18
MW-305	10.11.19/1030	14.29	7.36	0.20	795	-132.9	3.02
MW-306	10.11.19/1116	14.28	10.53	0.21	473	-165.1	1.84
MW-307	10.11.19/1206	14.37	10.14	0.24	536	-126.3	3.23
MW-308	10.10.19/1008	14.64	9.42	0.21	671	-82.6	2.93
MW-309	10.11.19/0944	13.73	7.19	0.21	1,040	-165.6	8.93
MW-310	10.11.19/0802	15.88	6.95	0.28	961	-189.7	5.23
MW-311	10.11.19/0854	14.19	7.07	0.30	1,088	-163.4	13.4
MW-312	10.10.19/1522	15.6	7.19	8.75	785	-163.8	2.56
MW-313	10.10.19/1436	16.04	7.06	0.37	1,007	-163.4	11.03

Abbreviations:
mg/L = milligrams per liter
mV = millivolts
amsl = above mean sea level
µmhos/cm = micromohs per cm

Notes:
None

Created by: MDB Date: 6/11/2019
Last revision by: LWJ Date: 10/17/2019
Checked by: JSN Date: 10/18/2019

\\Mad-fs01\data\Projects\25219066.00\Data and Calculations\Tables\Field Data\[BGS_CCR_Field_1910.xlsx]GW Field Parameters

eurofins | Environment Testing
TestAmerica

ANALYTICAL REPORT

Eurofins TestAmerica, Cedar Falls
3019 Venture Way
Cedar Falls, IA 50613
Tel: (319)277-2401

Laboratory Job ID: 310-167314-2
Client Project/Site: Burlington Gen Station 25216066
Revision: 1

For:
SCS Engineers
2830 Dairy Drive
Madison, Wisconsin 53718

Attn: Meghan Blodgett

Authorized for release by:
12/27/2019 10:38:38 AM

Sandie Fredrick, Project Manager II
(920)261-1660
sandie.fredrick@testamericainc.com

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This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Case Narrative

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Job ID: 310-167314-2

Laboratory: Eurofins TestAmerica, Cedar Falls

Narrative

Job Narrative
310-167314-2

Comments
REVISION: Updated negative result for the Field blank for Radium.

Receipt
The samples were received on 10/12/2019 9:45 AM; the samples arrived in good condition, properly preserved and, where required, on ice. The temperatures of the 3 coolers at receipt time were 0.1º C, 0.5º C and 1.3º C.

RAD
Method 903.0: Radium-226 prep batch 160-446365- Any minimum detectable concentration (MDC), critical value (DLC), or Safe Drinking Water Act detection limit (SDWA DL) is sample-specific unless otherwise stated elsewhere in this narrative.

Radiochemistry sample results are reported with the count date/time applied as the Activity Reference Date.
MW-301 (310-167314-1), MW-302 (310-167314-2), MW-303 (310-167314-3), MW-304 (310-167314-4), MW-305 (310-167314-5), MW-306 (310-167314-6), MW-307 (310-167314-7), MW-308 (310-167314-8), MW-309 (310-167314-9), MW-310 (310-167314-10), MW-311 (310-167314-11), MW-312 (310-167314-12), MW-313 (310-167314-13), Field Blank (310-167314-14), (LCS 160-446365/1-A), (LCSD 160-446365/2-A) and (MB 160-446365/17-A)

Method 904.0: Radium-228 Prep Batch 160-446409 - Any minimum detectable concentration (MDC), critical value (DLC), or Safe Drinking Water Act detection limit (SDWA DL) is sample-specific unless otherwise stated elsewhere in this narrative.

Radiochemistry sample results are reported with the count date/time applied as the Activity Reference Date.
MW-301 (310-167314-1), MW-302 (310-167314-2), MW-303 (310-167314-3), MW-304 (310-167314-4), MW-305 (310-167314-5), MW-306 (310-167314-6), MW-307 (310-167314-7), MW-308 (310-167314-8), MW-309 (310-167314-9), MW-310 (310-167314-10), MW-311 (310-167314-11), MW-312 (310-167314-12), MW-313 (310-167314-13), Field Blank (310-167314-14), (LCS 160-446409/1-A), (LCSD 160-446409/2-A) and (MB 160-446409/17-A)

Method PrecSep_0: Radium 228 Prep Batch 160-446409: Insufficient sample volume was available to perform a sample duplicate for the following samples: MW-301 (310-167314-1), MW-302 (310-167314-2), MW-303 (310-167314-3), MW-304 (310-167314-4), MW-305 (310-167314-5), MW-306 (310-167314-6), MW-307 (310-167314-7), MW-308 (310-167314-8), MW-309 (310-167314-9), MW-310 (310-167314-10), MW-311 (310-167314-11), MW-312 (310-167314-12), MW-313 (310-167314-13) and Field Blank (310-167314-14). A laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) were prepared instead to demonstrate batch precision.

Method PrecSep-21: Radium 226 Prep Batch 160-446365: Insufficient sample volume was available to perform a sample duplicate for the following samples: MW-301 (310-167314-1), MW-302 (310-167314-2), MW-303 (310-167314-3), MW-304 (310-167314-4), MW-305 (310-167314-5), MW-306 (310-167314-6), MW-307 (310-167314-7), MW-308 (310-167314-8), MW-309 (310-167314-9), MW-310 (310-167314-10), MW-311 (310-167314-11), MW-312 (310-167314-12), MW-313 (310-167314-13) and Field Blank (310-167314-14). A laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) were prepared instead to demonstrate batch precision.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

Sample Summary

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received	Asset ID
310-167314-1	MW-301	Water	10/10/19 11:02	10/12/19 09:45	
310-167314-2	MW-302	Water	10/10/19 12:12	10/12/19 09:45	
310-167314-3	MW-303	Water	10/10/19 13:00	10/12/19 09:45	
310-167314-4	MW-304	Water	10/10/19 13:44	10/12/19 09:45	
310-167314-5	MW-305	Water	10/11/19 10:30	10/12/19 09:45	
310-167314-6	MW-306	Water	10/11/19 11:16	10/12/19 09:45	
310-167314-7	MW-307	Water	10/11/19 15:06	10/12/19 09:45	
310-167314-8	MW-308	Water	10/10/19 10:08	10/12/19 09:45	
310-167314-9	MW-309	Water	10/11/19 09:44	10/12/19 09:45	
310-167314-10	MW-310	Water	10/11/19 08:02	10/12/19 09:45	
310-167314-11	MW-311	Water	10/11/19 08:54	10/12/19 09:45	
310-167314-12	MW-312	Water	10/10/19 15:22	10/12/19 09:45	
310-167314-13	MW-313	Water	10/10/19 14:36	10/12/19 09:45	
310-167314-14	Field Blank	Water	10/10/19 23:59	10/12/19 09:45	

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Client Sample ID: MW-301
Date Collected: 10/10/19 11:02
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-1
Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.498		0.155	0.161	1.00	0.152	pCi/L	10/16/19 07:28	11/07/19 09:34	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*78.2*		*40 - 110*	*10/16/19 07:28*	*11/07/19 09:34*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.527		0.304	0.308	1.00	0.460	pCi/L	10/16/19 08:00	10/31/19 17:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*78.2*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:35*	*1*
Y Carrier	*88.2*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:35*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	1.03		0.341	0.348	5.00	0.460	pCi/L		11/27/19 10:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Client Sample ID: MW-302

Date Collected: 10/10/19 12:12
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-2
Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.374**		0.132	0.137	1.00	0.135	pCi/L	10/16/19 07:28	11/07/19 09:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*82.8*		*40 - 110*	*10/16/19 07:28*	*11/07/19 09:35*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.270	U	0.258	0.259	1.00	0.417	pCi/L	10/16/19 08:00	10/31/19 17:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*82.8*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:35*	*1*
Y Carrier	*93.1*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:35*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**0.644**		0.290	0.293	5.00	0.417	pCi/L		11/27/19 10:32	1

Client Sample Results

Client: SCS Engineers
Job ID: 310-167314-2
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-303
Lab Sample ID: 310-167314-3
Date Collected: 10/10/19 13:00
Matrix: Water
Date Received: 10/12/19 09:45

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.728**		0.180	0.192	1.00	0.164	pCi/L	10/16/19 07:28	11/07/19 09:34	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*82.2*		*40 - 110*	*10/16/19 07:28*	*11/07/19 09:34*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.316	U	0.270	0.272	1.00	0.429	pCi/L	10/16/19 08:00	10/31/19 17:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*82.2*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:35*	*1*
Y Carrier	*82.2*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:35*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**1.04**		0.324	0.333	5.00	0.429	pCi/L		11/27/19 10:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Client Sample ID: MW-304
Date Collected: 10/10/19 13:44
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-4
Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.353**		0.151	0.154	1.00	0.183	pCi/L	10/16/19 07:28	11/07/19 09:34	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*71.8*		*40 - 110*	*10/16/19 07:28*	*11/07/19 09:34*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.428	U	0.320	0.322	1.00	0.501	pCi/L	10/16/19 08:00	10/31/19 17:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*71.8*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:35*	*1*
Y Carrier	*83.4*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:35*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**0.781**		0.354	0.357	5.00	0.501	pCi/L		11/27/19 10:32	1

Client Sample ID: MW-305

Date Collected: 10/11/19 10:30
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-5
Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.256**		0.129	0.131	1.00	0.167	pCi/L	10/16/19 07:28	11/07/19 09:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*73.2*		*40 - 110*	*10/16/19 07:28*	*11/07/19 09:35*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.185	U	0.348	0.349	1.00	0.591	pCi/L	10/16/19 08:00	10/31/19 17:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*73.2*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:35*	*1*
Y Carrier	*82.2*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:35*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	0.441	U	0.371	0.373	5.00	0.591	pCi/L		11/27/19 10:32	1

Client Sample ID: MW-306

Date Collected: 10/11/19 11:16
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-6
Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.210**		0.133	0.135	1.00	0.183	pCi/L	10/16/19 07:28	11/07/19 09:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*65.8*		*40 - 110*	*10/16/19 07:28*	*11/07/19 09:35*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.316	U	0.424	0.425	1.00	0.705	pCi/L	10/16/19 08:00	10/31/19 17:37	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*65.8*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:37*	*1*
Y Carrier	*83.7*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:37*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	0.526	U	0.444	0.446	5.00	0.705	pCi/L		11/27/19 10:32	1

Client: SCS Engineers
Job ID: 310-167314-2
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-307
Lab Sample ID: 310-167314-7
Date Collected: 10/11/19 15:06
Matrix: Water
Date Received: 10/12/19 09:45

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.218**		0.115	0.117	1.00	0.147	pCi/L	10/16/19 07:28	11/07/19 09:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*83.1*		*40 - 110*	*10/16/19 07:28*	*11/07/19 09:35*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.0141	U	0.334	0.334	1.00	0.590	pCi/L	10/16/19 08:00	10/31/19 17:37	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*83.1*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:37*	*1*
Y Carrier	*75.5*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:37*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	0.232	U	0.353	0.354	5.00	0.590	pCi/L		11/27/19 10:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Client Sample ID: MW-308

Date Collected: 10/10/19 10:08
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-8
Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.202**		0.101	0.102	1.00	0.128	pCi/L	10/16/19 07:28	11/07/19 09:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*99.7*		*40 - 110*	*10/16/19 07:28*	*11/07/19 09:35*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.0862	U	0.261	0.262	1.00	0.451	pCi/L	10/16/19 08:00	10/31/19 17:38	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*99.7*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*
Y Carrier	*82.2*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	0.288	U	0.280	0.281	5.00	0.451	pCi/L		11/27/19 10:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Client Sample ID: MW-309

Date Collected: 10/11/19 09:44
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-9
Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.274**		0.124	0.126	1.00	0.157	pCi/L	10/16/19 07:28	11/07/19 09:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*92.4*		*40 - 110*	*10/16/19 07:28*	*11/07/19 09:35*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.322	U	0.326	0.327	1.00	0.532	pCi/L	10/16/19 08:00	10/31/19 17:38	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*92.4*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*
Y Carrier	*81.5*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**0.596**		0.349	0.350	5.00	0.532	pCi/L		11/27/19 10:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Client Sample ID: MW-310
Date Collected: 10/11/19 08:02
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-10
Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.473**		0.137	0.143	1.00	0.130	pCi/L	10/16/19 07:28	11/07/19 09:35	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*106*		*40 - 110*	*10/16/19 07:28*	*11/07/19 09:35*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.0174	U	0.200	0.200	1.00	0.352	pCi/L	10/16/19 08:00	10/31/19 17:38	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*106*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*
Y Carrier	*96.1*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**0.490**		0.242	0.246	5.00	0.352	pCi/L		11/27/19 10:32	1

Client Sample Results

Client: SCS Engineers
Job ID: 310-167314-2
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-311
Lab Sample ID: 310-167314-11
Date Collected: 10/11/19 08:54
Matrix: Water
Date Received: 10/12/19 09:45

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.354**		0.129	0.133	1.00	0.142	pCi/L	10/16/19 07:28	11/07/19 09:36	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*95.5*		*40 - 110*	*10/16/19 07:28*	*11/07/19 09:36*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.245	U	0.260	0.261	1.00	0.425	pCi/L	10/16/19 08:00	10/31/19 17:38	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*95.5*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*
Y Carrier	*92.0*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	**0.599**		0.290	0.293	5.00	0.425	pCi/L		11/27/19 10:32	1

Client Sample ID: MW-312
Date Collected: 10/10/19 15:22
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-12
Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.433**		0.137	0.142	1.00	0.138	pCi/L	10/16/19 07:28	11/07/19 12:45	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*89.8*		*40 - 110*	*10/16/19 07:28*	*11/07/19 12:45*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.00445	U	0.273	0.273	1.00	0.481	pCi/L	10/16/19 08:00	10/31/19 17:38	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*89.8*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*
Y Carrier	*91.6*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	0.438	U	0.305	0.308	5.00	0.481	pCi/L		11/27/19 10:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Client Sample ID: MW-313
Date Collected: 10/10/19 14:36
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-13
Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.968		0.197	0.216	1.00	0.160	pCi/L	10/16/19 07:28	11/07/19 12:45	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*87.3*		*40 - 110*	*10/16/19 07:28*	*11/07/19 12:45*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.736		0.329	0.336	1.00	0.475	pCi/L	10/16/19 08:00	10/31/19 17:38	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*87.3*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*
Y Carrier	*80.4*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	1.70		0.383	0.399	5.00	0.475	pCi/L		11/27/19 10:32	1

Client Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Client Sample ID: Field Blank
Date Collected: 10/10/19 23:59
Date Received: 10/12/19 09:45

Lab Sample ID: 310-167314-14
Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.141**		0.0963	0.0971	1.00	0.137	pCi/L	10/16/19 07:28	11/07/19 12:45	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*90.4*		*40 - 110*	*10/16/19 07:28*	*11/07/19 12:45*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	-0.0591	U	0.228	0.228	1.00	0.421	pCi/L	10/16/19 08:00	10/31/19 17:38	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*90.4*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*
Y Carrier	*84.9*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*

Method: Ra226_Ra228 Pos - Combined Radium-226 and Radium-228

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium 226 and 228	0.141	U	0.248	0.248	5.00	0.421	pCi/L		11/27/19 10:32	1

Definitions/Glossary

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Qualifiers

Rad

Qualifier	Qualifier Description
U	Result is less than the sample detection limit.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

QC Sample Results

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Method: 903.0 - Radium-226 (GFPC)

Lab Sample ID: MB 160-446365/17-A
Matrix: Water
Analysis Batch: 449488

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 446365

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.07342	U	0.0904	0.0906	1.00	0.150	pCi/L	10/16/19 07:28	11/07/19 12:45	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*91.2*		*40 - 110*	*10/16/19 07:28*	*11/07/19 12:45*	*1*

Lab Sample ID: LCS 160-446365/1-A
Matrix: Water
Analysis Batch: 452083

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 446365

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-226	11.3	8.945		0.952	1.00	0.136	pCi/L	79	75 - 125

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*80.8*		*40 - 110*

Lab Sample ID: LCSD 160-446365/2-A
Matrix: Water
Analysis Batch: 449488

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 446365

Analyte	Spike Added	LCSD Result	LCSD Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits	RER	RER Limit
Radium-226	11.4	8.851		0.969	1.00	0.115	pCi/L	78	75 - 125	0.05	1

Carrier	*LCSD %Yield*	*LCSD Qualifier*	*Limits*
Ba Carrier	*85.9*		*40 - 110*

Method: 904.0 - Radium-228 (GFPC)

Lab Sample ID: MB 160-446409/17-A
Matrix: Water
Analysis Batch: 448507

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 446409

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	-0.09953	U	0.244	0.244	1.00	0.454	pCi/L	10/16/19 08:00	10/31/19 17:38	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*91.2*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*
Y Carrier	*81.5*		*40 - 110*	*10/16/19 08:00*	*10/31/19 17:38*	*1*

Method: 904.0 - Radium-228 (GFPC) (Continued)

Lab Sample ID: LCS 160-446409/1-A
Client Sample ID: Lab Control Sample
Matrix: Water
Prep Type: Total/NA
Analysis Batch: 448459
Prep Batch: 446409

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-228	9.44	10.87		1.27	1.00	0.473	pCi/L	115	75 - 125

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*80.8*		*40 - 110*
Y Carrier	*85.2*		*40 - 110*

Lab Sample ID: LCSD 160-446409/2-A
Client Sample ID: Lab Control Sample Dup
Matrix: Water
Prep Type: Total/NA
Analysis Batch: 448459
Prep Batch: 446409

Analyte	Spike Added	LCSD Result	LCSD Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits	RER	RER Limit
Radium-228	9.44	10.19		1.20	1.00	0.428	pCi/L	108	75 - 125	0.27	1

Carrier	*LCSD %Yield*	*LCSD Qualifier*	*Limits*
Ba Carrier	*85.9*		*40 - 110*
Y Carrier	*80.7*		*40 - 110*

Rad

Prep Batch: 446365

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-1	MW-301	Total/NA	Water	PrecSep-21	
310-167314-2	MW-302	Total/NA	Water	PrecSep-21	
310-167314-3	MW-303	Total/NA	Water	PrecSep-21	
310-167314-4	MW-304	Total/NA	Water	PrecSep-21	
310-167314-5	MW-305	Total/NA	Water	PrecSep-21	
310-167314-6	MW-306	Total/NA	Water	PrecSep-21	
310-167314-7	MW-307	Total/NA	Water	PrecSep-21	
310-167314-8	MW-308	Total/NA	Water	PrecSep-21	
310-167314-9	MW-309	Total/NA	Water	PrecSep-21	
310-167314-10	MW-310	Total/NA	Water	PrecSep-21	
310-167314-11	MW-311	Total/NA	Water	PrecSep-21	
310-167314-12	MW-312	Total/NA	Water	PrecSep-21	
310-167314-13	MW-313	Total/NA	Water	PrecSep-21	
310-167314-14	Field Blank	Total/NA	Water	PrecSep-21	
MB 160-446365/17-A	Method Blank	Total/NA	Water	PrecSep-21	
LCS 160-446365/1-A	Lab Control Sample	Total/NA	Water	PrecSep-21	
LCSD 160-446365/2-A	Lab Control Sample Dup	Total/NA	Water	PrecSep-21	

Prep Batch: 446409

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
310-167314-1	MW-301	Total/NA	Water	PrecSep_0	
310-167314-2	MW-302	Total/NA	Water	PrecSep_0	
310-167314-3	MW-303	Total/NA	Water	PrecSep_0	
310-167314-4	MW-304	Total/NA	Water	PrecSep_0	
310-167314-5	MW-305	Total/NA	Water	PrecSep_0	
310-167314-6	MW-306	Total/NA	Water	PrecSep_0	
310-167314-7	MW-307	Total/NA	Water	PrecSep_0	
310-167314-8	MW-308	Total/NA	Water	PrecSep_0	
310-167314-9	MW-309	Total/NA	Water	PrecSep_0	
310-167314-10	MW-310	Total/NA	Water	PrecSep_0	
310-167314-11	MW-311	Total/NA	Water	PrecSep_0	
310-167314-12	MW-312	Total/NA	Water	PrecSep_0	
310-167314-13	MW-313	Total/NA	Water	PrecSep_0	
310-167314-14	Field Blank	Total/NA	Water	PrecSep_0	
MB 160-446409/17-A	Method Blank	Total/NA	Water	PrecSep_0	
LCS 160-446409/1-A	Lab Control Sample	Total/NA	Water	PrecSep_0	
LCSD 160-446409/2-A	Lab Control Sample Dup	Total/NA	Water	PrecSep_0	

Lab Chronicle

Client: SCS Engineers
Job ID: 310-167314-2
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-301
Lab Sample ID: 310-167314-1
Date Collected: 10/10/19 11:02
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 09:34	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448459	10/31/19 17:35	SCB	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Client Sample ID: MW-302
Lab Sample ID: 310-167314-2
Date Collected: 10/10/19 12:12
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 09:35	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448459	10/31/19 17:35	SCB	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Client Sample ID: MW-303
Lab Sample ID: 310-167314-3
Date Collected: 10/10/19 13:00
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 09:34	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448459	10/31/19 17:35	SCB	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Client Sample ID: MW-304
Lab Sample ID: 310-167314-4
Date Collected: 10/10/19 13:44
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 09:34	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448459	10/31/19 17:35	SCB	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Lab Chronicle

Client: SCS Engineers
Job ID: 310-167314-2
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-305
Lab Sample ID: 310-167314-5
Date Collected: 10/11/19 10:30
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 09:35	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448459	10/31/19 17:35	SCB	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Client Sample ID: MW-306
Lab Sample ID: 310-167314-6
Date Collected: 10/11/19 11:16
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 09:35	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448507	10/31/19 17:37	KLS	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Client Sample ID: MW-307
Lab Sample ID: 310-167314-7
Date Collected: 10/11/19 15:06
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 09:35	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448507	10/31/19 17:37	KLS	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Client Sample ID: MW-308
Lab Sample ID: 310-167314-8
Date Collected: 10/10/19 10:08
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 09:35	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448507	10/31/19 17:38	KLS	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Lab Chronicle

Client: SCS Engineers
Job ID: 310-167314-2
Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-309
Lab Sample ID: 310-167314-9

Date Collected: 10/11/19 09:44
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 09:35	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448507	10/31/19 17:38	KLS	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Client Sample ID: MW-310
Lab Sample ID: 310-167314-10

Date Collected: 10/11/19 08:02
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 09:35	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448507	10/31/19 17:38	KLS	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Client Sample ID: MW-311
Lab Sample ID: 310-167314-11

Date Collected: 10/11/19 08:54
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 09:36	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448507	10/31/19 17:38	KLS	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Client Sample ID: MW-312
Lab Sample ID: 310-167314-12

Date Collected: 10/10/19 15:22
Matrix: Water
Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 12:45	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448507	10/31/19 17:38	KLS	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Lab Chronicle

Client: SCS Engineers | Job ID: 310-167314-2

Project/Site: Burlington Gen Station 25216066

Client Sample ID: MW-313

Lab Sample ID: 310-167314-13

Date Collected: 10/10/19 14:36

Matrix: Water

Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 12:45	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448507	10/31/19 17:38	KLS	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Client Sample ID: Field Blank

Lab Sample ID: 310-167314-14

Date Collected: 10/10/19 23:59

Matrix: Water

Date Received: 10/12/19 09:45

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			446365	10/16/19 07:28	EJQ	TAL SL
Total/NA	Analysis	903.0		1	449488	11/07/19 12:45	KLS	TAL SL
Total/NA	Prep	PrecSep_0			446409	10/16/19 08:00	EJQ	TAL SL
Total/NA	Analysis	904.0		1	448507	10/31/19 17:38	KLS	TAL SL
Total/NA	Analysis	Ra226_Ra228 Pos		1	455420	11/27/19 10:32	SCB	TAL SL

Laboratory References:

TAL SL = Eurofins TestAmerica, St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Accreditation/Certification Summary

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Laboratory: Eurofins TestAmerica, Cedar Falls

The accreditations/certifications listed below are applicable to this report.

Authority	Program	Identification Number	Expiration Date
Iowa	State Program	007	12-01-19 *

Laboratory: Eurofins TestAmerica, St. Louis

All accreditations/certifications held by this laboratory are listed. Not all accreditations/certifications are applicable to this report.

Authority	Program	Identification Number	Expiration Date
ANAB	Dept. of Defense ELAP	L2305	04-06-22
ANAB	Dept. of Energy	L2305.01	04-06-22
ANAB	ISO/IEC 17025	L2305	04-06-22
Arizona	State	AZ0813	12-08-19
California	Los Angeles County Sanitation Districts	10259	06-30-20
California	State	2886	06-30-20
Connecticut	State	PH-0241	03-31-21
Florida	NELAP	E87689	06-30-20
HI - RadChem Recognition	State	n/a	06-30-20
Illinois	NELAP	004553	11-30-19
Iowa	State	373	09-17-20
Kansas	NELAP	E-10236	10-31-20
Kentucky (DW)	State	KY90125	12-31-19
Louisiana	NELAP	04080	06-30-20
Louisiana (DW)	State	LA011	12-31-19
Maryland	State	310	09-30-20
MI - RadChem Recognition	State	9005	06-30-20
Missouri	State	780	06-30-22
Nevada	State	MO000542020-1	07-31-20
New Jersey	NELAP	MO002	06-30-20
New York	NELAP	11616	04-01-20
North Dakota	State	R-207	06-30-20
NRC	NRC	24-24817-01	12-31-22
Oklahoma	State	9997	08-31-20
Pennsylvania	NELAP	68-00540	02-28-20
South Carolina	State	85002001	06-30-20
Texas	NELAP	T104704193-19-13	07-31-20
US Fish & Wildlife	US Federal Programs	058448	07-31-20
USDA	US Federal Programs	P330-17-00028	02-02-20
Utah	NELAP	MO000542019-11	07-31-20
Virginia	NELAP	10310	06-14-20
Washington	State	C592	08-30-20
West Virginia DEP	State	381	12-31-19

* Accreditation/Certification renewal pending - accreditation/certification considered valid.

Method Summary

Client: SCS Engineers
Project/Site: Burlington Gen Station 25216066

Job ID: 310-167314-2

Method	Method Description	Protocol	Laboratory
903.0	Radium-226 (GFPC)	EPA	TAL SL
904.0	Radium-228 (GFPC)	EPA	TAL SL
Ra226_Ra228 Pos	Combined Radium-226 and Radium-228	TAL-STL	TAL SL
PrecSep_0	Preparation, Precipitate Separation	None	TAL SL
PrecSep-21	Preparation, Precipitate Separation (21-Day In-Growth)	None	TAL SL

Protocol References:

EPA = US Environmental Protection Agency

None = None

TAL-STL = TestAmerica Laboratories, St. Louis, Facility Standard Operating Procedure.

Laboratory References:

TAL SL = Eurofins TestAmerica, St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

eurofins | Environment Testing
TestAmerica

310-167314 Chain of Custody

Cooler/Sample Receipt and Temperature Log Form

Client Information

Client: SCS Engineers

City/State: CITY Clive STATE IA | Project: Burlington Gen Station

Receipt Information

Date/Time Received: DATE 10-12-19 TIME 945 | Received By: LAB

Delivery Type: ☐ UPS ☒ FedEx sat ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee
☐ Lab Courier ☐ Lab Field Services ☐ Client Drop-off ☐ Other:________

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes	☐ No	*If yes:* Cooler ID:
Multiple Coolers?	☒ Yes	☐ No	*If yes:* Cooler # 1 of 3
Cooler Custody Seals Present?	☒ Yes	☐ No	*If yes:* Cooler custody seals intact? ☐ Yes ☐ No
Sample Custody Seals Present?	☐ Yes	☒ No	*If yes:* Sample custody seals intact? ☐ Yes ☐ No
Trip Blank Present?	☐ Yes	☒ No	*If yes:* Which VOA samples are in cooler? ↓

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:________ ☐ NONE

Thermometer ID: N | Correction Factor (°C): +0.0

• Temp Blank Temperature – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): 0.5 | Corrected Temp (°C): 0.5

• Sample Container Temperature

Container(s) used:	CONTAINER 1	CONTAINER 2
Uncorrected Temp (°C):		
Corrected Temp (°C):		

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

Document: CF-LG-WI-002
Revision: 25
Date: 06/17/2019

Eurofins TestAmerica, Cedar Falls

General temperature criteria is 0 to 6°C
Bacteria temperature criteria is 0 to 10°C

eurofins | Environment Testing TestAmerica

Place COC scanning label here

Cooler/Sample Receipt and Temperature Log Form

Client Information

Client: SCS Engineers

City/State: CITY Clive STATE IA | Project: Burlington Gen Station

Receipt Information

Date/Time Received: DATE 10-12-19 TIME 945 | Received By: LAB

Delivery Type: ☐ UPS ☒ FedEx sat ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee ☐ Lab Courier ☐ Lab Field Services ☐ Client Drop-off ☐ Other:____________

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes	☐ No	*If yes:* Cooler ID:
Multiple Coolers?	☒ Yes	☐ No	*If yes:* Cooler # 2 of 3
Cooler Custody Seals Present?	☒ Yes	☐ No	*If yes:* Cooler custody seals intact? ☐ Yes ☐ No
Sample Custody Seals Present?	☐ Yes	☒ No	*If yes:* Sample custody seals intact? ☐ Yes ☐ No
Trip Blank Present?	☐ Yes	☒ No	*If yes:* Which VOA samples are in cooler? ↓

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:____________ ☐ NONE

Thermometer ID: N | Correction Factor (°C): +0.0

• Temp Blank Temperature – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): 0.1 | Corrected Temp (°C): 0.1

• Sample Container Temperature

Container(s) used:	CONTAINER 1	CONTAINER 2
Uncorrected Temp (°C):		
Corrected Temp (°C):		

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

Document: CF-LG-WI-002
Revision: 25
Date: 06/17/2019

Eurofins TestAmerica, Cedar Falls

General temperature criteria is 0 to 6°C
Bacteria temperature criteria is 0 to 10°C

eurofins | Environment Testing TestAmerica

Place COC scanning label here

Cooler/Sample Receipt and Temperature Log Form

Client Information			
Client: SCS Engineers			
City/State: CITY Clive	STATE IA	Project: Burlington Gen Station	
Receipt Information			
Date/Time Received: DATE 10-12-19	TIME 945	Received By: LAB	

Delivery Type: ☐ UPS ☒ FedEx sat ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee ☐ Lab Courier ☐ Lab Field Services ☐ Client Drop-off ☐ Other:____________

Condition of Cooler/Containers			
Sample(s) received in Cooler?	☒ Yes	☐ No	*If yes:* Cooler ID:
Multiple Coolers?	☒ Yes	☐ No	*If yes:* Cooler # 3 of 3
Cooler Custody Seals Present?	☒ Yes	☐ No	*If yes:* Cooler custody seals intact? ☐ Yes ☐ No
Sample Custody Seals Present?	☐ Yes	☒ No	*If yes:* Sample custody seals intact? ☐ Yes ☐ No
Trip Blank Present?	☐ Yes	☒ No	*If yes:* Which VOA samples are in cooler? ↓

Temperature Record	
Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:________ ☐ NONE	
Thermometer ID: N	Correction Factor (°C): +0.0
• Temp Blank Temperature – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature	
Uncorrected Temp (°C): 1.3	Corrected Temp (°C): 1.3

• Sample Container Temperature

	CONTAINER 1	CONTAINER 2
Container(s) used:		
Uncorrected Temp (°C):		
Corrected Temp (°C):		

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

Table 1. Sampling Points and Parameters - CCR Rule Sampling Program Assessment Monitoring Groundwater Monitoring - Burlington Generating Station / SCS Engineers Project #25216066

	Parameter	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306	MW-307	MW-308	MW-309	MW-310	MW-311	MW-312	MW-313	Field Blank	TOTAL
Appendix III Parameters	Boron	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Calcium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Chloride	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Fluoride	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	pH	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Sulfate	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	TDS	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
Appendix IV Parameters	Antimony	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Arsenic	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Barium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Beryllium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Cadmium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Chromium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Cobalt	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Fluoride	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Lead	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Lithium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Mercury															0
	Molybdenum	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Selenium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
	Thallium															0
	Radium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	14
Field Parameters	Groundwater Elevation	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Well Depth	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	pH (field)	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Specific Conductance	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Dissolved Oxygen	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	ORP	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Temperature	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Turbidity	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Color	x	x	x	x	x	x	x	x	x	x	x	x	x		13
	Odor	x	x	x	x	x	x	x	x	x	x	x	x	x		13

Notes: All samples are unfiltered (total).

I:\25219066.00\Data and Calculations\Field Work Requests\[Table_1_BGS_CCR_Rule_Sampling_1910.xls]Sheet1

Eurofins TestAmerica, Cedar Falls
3019 Venture Way
Cedar Falls, IA 50613
Phone: 319-277-2401 Fax: 319-277-2425

Chain of Custody Record

TestAmerica Des Moines SC
214

eurofins Environment Testing TestAmerica

43467

Client Information	Sampler: Louise Jennings	Lab PM: Fredrick, Sandie	Carrier Tracking No(s):	COC No: 310-43667-14046.1
Client Contact: Louise Jennings	Phone: 608 509 8245	E-Mail: sandie.fredrick@testamericainc.com		Page: Page 1 of 2
Company: SCS Engineers		Analysis Requested		Job #:
Address: 8450 Hickman Road Suite 20	Due Date Requested:			Preservation Codes: A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA, M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
City: Clive	TAT Requested (days): Standard			
State, Zip: IA, 50325				
Phone:	PO #: 25216066			
Email: ljennings@scsengineers.com	WO #:			
Project Name: Burlington Gen Station 25216066	Project #: 31011020			Other:
Site:	SSOW#:			

Sample Identification	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	6020A - Metals - Hg	2540C_Calcd, 9056A_ORGFM_28D, SM4500_H+	903.0 - Radium 226	904.0 - Radium 228	Total Number of containers	Special Instructions/Note:
				Preservation Code:			D	N	D	D		
MW-301	10.10.19	1102	G	Water			X	X	X	X		
MW-302	10.10.19	1212	G	Water			↓	↓	↓	↓		
MW-303	10/10/19	1300	G	Water			↓	↓	↓	↓		
MW-304	10.10.19	1344	G	Water			↓	↓	↓	↓		
MW-305	10.11.19	1030	G	Water			↓	↓	↓	↓		
MW-306	10.11.19	1110	G	Water			↓	↓	↓	↓		
MW-307	10.11.19	1206	G	Water			↓	↓	↓	↓		
MW-308	10.10.19	1008	G	Water			↓	↓	↓	↓		
MW-309	10.11.19	0944	G	Water			↓	↓	↓	↓		
MW-310	10.11.19	0802	G	Water			↓	↓	↓	↓		
MW-311	10.11.19	0854	G	Water			↓	↓	↓	↓		

Possible Hazard Identification
☐ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown ☐ Radiological

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months

Deliverable Requested: I, II, III, IV, Other (specify)

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:		
Relinquished by: L Jennings	Date/Time: 10.11.19 16:15	Company: SCS	Received by: Lindsay Bindert	Date/Time: 10-12-19 945	Company: ETA
Relinquished by:	Date/Time:	Company:	Received by:	Date/Time:	Company:
Relinquished by:	Date/Time:	Company:	Received by:	Date/Time:	Company:

Custody Seals Intact: Δ Yes Δ No | Custody Seal No.: | Cooler Temperature(s) °C and Other Remarks:

12/27/2019 (Rev. 1)

14 13 12 11 10 9 8 7 6 5 4 3 2 1

Eurofins TestAmerica, Cedar Falls
3019 Venture Way
Cedar Falls, IA 50613
Phone (319) 277-2401 Fax (319) 277-2425

Chain of Custody Record

TestAmerica Des Moines SC
214

eurofins | Environment Testing TestAmerica

43467

Client Information	Sampler: Louise Jennings	Lab PM: Fredrick, Sandie	Carrier Tracking No(s):	COC No: 310-43667-14046.2
Client Contact: Louise Jennings	Phone: 608 509 8845	E-Mail: sandie.fredrick@testamericainc.com		Page: Page 2 of 2
Company: SCS Engineers		**Analysis Requested**		Job #:
Address: 8450 Hickman Road Suite 20	Due Date Requested:			
City: Clive	TAT Requested (days): Standard			
State, Zip: IA, 50325				
Phone:	PO #: 25216066			
Email: ljennings@scsengineers.com	WO #:			
Project Name: Burlington Gen Station 25216066	Project #: 31011020			
Site:	SSOW#:			

Preservation Codes:
A - HCL; B - NaOH; C - Zn Acetate; D - Nitric Acid; E - NaHSO4; F - MeOH; G - Amchlor; H - Ascorbic Acid; I - Ice; J - DI Water; K - EDTA; L - EDA
M - Hexane; N - None; O - AsNaO2; P - Na2O4S; Q - Na2SO3; R - Na2S2O3; S - H2SO4; T - TSP Dodecahydrate; U - Acetone; V - MCAA; W - pH 4-5; Z - other (specify)
Other:

Sample Identification	Sample Date	Sample Time	Sample Type (C=Comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	6020A - Metals - Hg	2540C_Calcd, 9056A_ORGFM_28D, SM4500_H+	903.0 - Radium 226	904.0 - Radium 228	Total Number of containers	Special Instructions/Note:
				Preservation Code:	X	X	D	N	D	D	X	
MW-312	10.10.19	1522	G	Water								
MW-313	10.10.19	1436	G	Water								
Field Blank	10.10.19	2359	—	Water								
				Water								

Possible Hazard Identification
☐ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown ☐ Radiological

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months

Deliverable Requested: I, II, III, IV, Other (specify)

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:

Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
L. Jennings	10.11.19 1615		Lindsay Bindert	10-12-19 945	ETA
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company

Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:	Cooler Temperature(s) °C and Other Remarks:

Login Container Summary Report

Temperature readings: ______________________________

Client Sample ID	Lab ID	Container Type	Container pH	Preservative Added (mls)	Lot #
MW-301	310-167314-A-1	Plastic 250ml - with Nitric Acid	<2		
MW-301	310-167314-B-1	Plastic 1 liter - Nitric Acid	<2		
MW-301	310-167314-C-1	Plastic 1 liter - Nitric Acid	<2		
MW-302	310-167314-A-2	Plastic 250ml - with Nitric Acid	<2		
MW-302	310-167314-B-2	Plastic 1 liter - Nitric Acid	<2		
MW-302	310-167314-C-2	Plastic 1 liter - Nitric Acid	<2		
MW-303	310-167314-A-3	Plastic 250ml - with Nitric Acid	<2		
MW-303	310-167314-B-3	Plastic 1 liter - Nitric Acid	<2		
MW-303	310-167314-C-3	Plastic 1 liter - Nitric Acid	<2		
MW-304	310-167314-A-4	Plastic 250ml - with Nitric Acid	<2		
MW-304	310-167314-B-4	Plastic 1 liter - Nitric Acid	<2		
MW-304	310-167314-C-4	Plastic 1 liter - Nitric Acid	<2		
MW-305	310-167314-A-5	Plastic 250ml - with Nitric Acid	<2		
MW-305	310-167314-B-5	Plastic 1 liter - Nitric Acid	<2		
MW-305	310-167314-C-5	Plastic 1 liter - Nitric Acid	<2		
MW-306	310-167314-A-6	Plastic 250ml - with Nitric Acid	<2		
MW-306	310-167314-B-6	Plastic 1 liter - Nitric Acid	<2		
MW-306	310-167314-C-6	Plastic 1 liter - Nitric Acid	<2		
MW-307	310-167314-A-7	Plastic 250ml - with Nitric Acid	<2		
MW-307	310-167314-B-7	Plastic 1 liter - Nitric Acid	<2		
MW-307	310-167314-C-7	Plastic 1 liter - Nitric Acid	<2		
MW-308	310-167314-A-8	Plastic 250ml - with Nitric Acid	<2		
MW-308	310-167314-B-8	Plastic 1 liter - Nitric Acid	<2		
MW-308	310-167314-C-8	Plastic 1 liter - Nitric Acid	<2		
MW-309	310-167314-A-9	Plastic 250ml - with Nitric Acid	<2		
MW-309	310-167314-B-9	Plastic 1 liter - Nitric Acid	<2		
MW-309	310-167314-C-9	Plastic 1 liter - Nitric Acid	<2		
MW-310	310-167314-A-10	Plastic 250ml - with Nitric Acid	<2		
MW-310	310-167314-B-10	Plastic 1 liter - Nitric Acid	<2		
MW-310	310-167314-C-10	Plastic 1 liter - Nitric Acid	<2		
MW-311	310-167314-A-11	Plastic 250ml - with Nitric Acid	<2		
MW-311	310-167314-B-11	Plastic 1 liter - Nitric Acid	<2		
MW-311	310-167314-C-11	Plastic 1 liter - Nitric Acid	<2		
MW-312	310-167314-A-12	Plastic 250ml - with Nitric Acid	<2		
MW-312	310-167314-B-12	Plastic 1 liter - Nitric Acid	<2		
MW-312	310-167314-C-12	Plastic 1 liter - Nitric Acid	<2		
MW-313	310-167314-A-13	Plastic 250ml - with Nitric Acid	<2		

Client Sample ID	Lab ID	Container Type	Container pH	Preservative Added (mls)	Lot #
MW-313	310-167314-B-13	Plastic 1 liter - Nitric Acid	<2		
MW-313	310-167314-C-13	Plastic 1 liter - Nitric Acid	<2		
Field Blank	310-167314-A-14	Plastic 250ml - with Nitric Acid	<2		
Field Blank	310-167314-B-14	Plastic 1 liter - Nitric Acid	<2		
Field Blank	310-167314-C-14	Plastic 1 liter - Nitric Acid	<2		

Login Sample Receipt Checklist

Client: SCS Engineers

Job Number: 310-167314-2
SDG Number:

Login Number: 167314
List Number: 1
Creator: Homolar, Dana J

List Source: Eurofins TestAmerica, Cedar Falls

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Login Sample Receipt Checklist

Client: SCS Engineers

Job Number: 310-167314-2
SDG Number:

Login Number: 167314
List Number: 2
Creator: Harris, Lorin C

List Source: Eurofins TestAmerica, St. Louis
List Creation: 10/15/19 01:12 PM

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	False	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	False	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	N/A	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Tracer/Carrier Summary

Client: SCS Engineers
Job ID: 310-167314-2
Project/Site: Burlington Gen Station 25216066

Method: 903.0 - Radium-226 (GFPC)

Matrix: Water
Prep Type: Total/NA

		Percent Yield (Acceptance Limits)
Lab Sample ID	Client Sample ID	Ba Carrier (40-110)
310-167314-1	MW-301	78.2
310-167314-2	MW-302	82.8
310-167314-3	MW-303	82.2
310-167314-4	MW-304	71.8
310-167314-5	MW-305	73.2
310-167314-6	MW-306	65.8
310-167314-7	MW-307	83.1
310-167314-8	MW-308	99.7
310-167314-9	MW-309	92.4
310-167314-10	MW-310	106
310-167314-11	MW-311	95.5
310-167314-12	MW-312	89.8
310-167314-13	MW-313	87.3
310-167314-14	Field Blank	90.4
LCS 160-446365/1-A	Lab Control Sample	80.8
LCSD 160-446365/2-A	Lab Control Sample Dup	85.9
MB 160-446365/17-A	Method Blank	91.2

Tracer/Carrier Legend

Ba Carrier = Ba Carrier

Method: 904.0 - Radium-228 (GFPC)

Matrix: Water
Prep Type: Total/NA

		Percent Yield (Acceptance Limits)	
Lab Sample ID	Client Sample ID	Ba Carrier (40-110)	Y Carrier (40-110)
310-167314-1	MW-301	78.2	88.2
310-167314-2	MW-302	82.8	93.1
310-167314-3	MW-303	82.2	82.2
310-167314-4	MW-304	71.8	83.4
310-167314-5	MW-305	73.2	82.2
310-167314-6	MW-306	65.8	83.7
310-167314-7	MW-307	83.1	75.5
310-167314-8	MW-308	99.7	82.2
310-167314-9	MW-309	92.4	81.5
310-167314-10	MW-310	106	96.1
310-167314-11	MW-311	95.5	92.0
310-167314-12	MW-312	89.8	91.6
310-167314-13	MW-313	87.3	80.4
310-167314-14	Field Blank	90.4	84.9
LCS 160-446409/1-A	Lab Control Sample	80.8	85.2
LCSD 160-446409/2-A	Lab Control Sample Dup	85.9	80.7
MB 160-446409/17-A	Method Blank	91.2	81.5

Tracer/Carrier Legend

Ba Carrier = Ba Carrier
Y Carrier = Y Carrier

Appendix B

Alternative Source Demonstration

Alternative Source Demonstration Assessment Monitoring

Burlington Generating Station
Burlington, Iowa

Prepared for:

Alliant Energy

SCS ENGINEERS

25219066.00 | April 15, 2019

2830 Dairy Drive
Madison, WI 53718-6751
608-224-2830

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Figures

Appendices

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PE CERTIFICATION

I, Eric J. Nelson, hereby certify that that the information in this alternate source demonstration is accurate and meets the requirements of 40 CFR 257.95(g)(3). This certification is based on my review of the groundwater data and related site information available for the Burlington Generating Station. I am a duly licensed Professional Engineer under the laws of the State of Iowa.

4/14/2019

(signature) (date)

Eric J. Nelson

(printed or typed name)

License number 23136

My license renewal date is December 31, 2020.

Pages or sheets covered by this seal:

Alternative Source Demonstration

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1.0 INTRODUCTION

This Alternative Source Demonstration (ASD) was prepared to support compliance with the groundwater monitoring requirements of the "Coal Combustion Residuals (CCR) Final Rule" published by the U.S. Environmental Protection Agency (USEPA) in the *Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule*, dated April 17, 2015 (USEPA, 2015), and subsequent amendments. Specifically, this report was prepared to fulfill the requirements of 40 CFR 257.95(g)(3)(ii). The applicable sections of the Rule are provided below in *italics*.

1.1 §257.95(G)(3) ALTERNATIVE SOURCE DEMONSTRATION REQUIREMENTS

(3) Within 90 days of finding that any of the constituents listed in appendix IV to this part have been detected at a statistically significant level exceeding the groundwater protection standards the owner or operator must either:

(i) Initiate an assessment of corrective measures as required by § 257.96; or

(ii) Demonstrate that a source other than the CCR unit caused the contamination, or that the statistically significant increase resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. Any such demonstration must be supported by a report that includes the factual or evidentiary basis for any conclusions and must be certified to be accurate by a qualified professional engineer or approval from the Participating State Director or approval from EPA where EPA is the permitting authority. If a successful demonstration is made, the owner or operator must continue monitoring in accordance with the assessment monitoring program pursuant to this section, and may return to detection monitoring if the constituents in Appendix III and Appendix IV of this part are at or below background as specified in paragraph (e) of this section. The owner or operator must also include the demonstration in the annual groundwater monitoring and corrective action report required by § 257.90(e), in addition to the certification by a qualified professional engineer or the approval from the Participating State Director or the approval from EPA where EPA is the permitting authority.

This ASD was performed in response to results indicating that constituents listed in appendix IV had been detected at a statistically significant level exceeding the groundwater protection standards (GPSs) during assessment monitoring under the CCR Rule at the Burlington Generating Station (BGS). GPS exceedances for assessment monitoring performed in 2018 were reported to Alliant Energy by SCS Engineers on January 14, 2019.

This ASD documents that some of the wells and parameters identified as exceeding GPSs in the January 2019 correspondence did not exceed the GPS at a statistically significant level based on additional testing and statistical evaluation.

1.2 SITE INFORMATION AND MAP

BGS is located along the west bank of the Mississippi River, about 5 miles south of the city of Burlington, in Des Moines County, Iowa. The postal address of the plant is 4282 Sullivan Slough Road, Burlington, Iowa. In addition to the coal-fired generating plant, the property also contains a coal stockpile, an Eco-Stone (C Stone) storage area, upper ash pond, lower pond, economizer ash pond, bottom ash pond, and ash seal and storm water pond.

The groundwater monitoring system at BGS is a multi-unit system. BGS includes four existing CCR Units:

- BGS Ash Seal Pond (existing CCR surface impoundment)
- BGS Main Ash Pond (existing CCR surface impoundment)
- BGS Economizer Ash Pond (existing CCR surface impoundment)
- BGS Upper Ash Pond (existing CCR surface impoundment)

A map showing the CCR Units and all background (or upgradient) and downgradient monitoring wells with identification numbers for the CCR groundwater monitoring program is provided as **Figure 1**.

1.3 GROUNDWATER PROTECTION STANDARD EXCEEDANCES IDENTIFIED

GPS exceedances were identified in the January 14, 2019, correspondence for the following wells and parameters:

- Lithium: MW-302, MW-303, MW-304, MW-306, MW-307, MW-308
- Molybdenum: MW-301, MW-302, MW-304, MW-307, MW-308

This initial evaluation of the assessment monitoring results was based on the first three sampling events for the Appendix IV assessment monitoring parameters. Samples were collected in May, August, and October 2018. For each of the well-parameter pairs listed above, at least one of the three results exceeded the GPS.

2.0 RETESTING AND ADDITIONAL STATISTICAL EVALUATION

For comparison of assessment monitoring data to fixed GPS values, the USEPA's Unified Guidance for Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (EPA 530-R-09-007, March 2009) recommends the use of confidence intervals. Specifically, the suggested approach for comparing assessment groundwater monitoring data to GPS values based on long-term chronic health risk, such as drinking water Maximum Contaminant Levels (MCLs), is to compare the lower confidence limit around the arithmetic mean with the fixed GPS. Although a confidence interval approach is recommended, a minimum of four samples are required for this approach, and only three assessment monitoring compliance samples had been collected at the time of the January 2019 evaluation; therefore, the initial evaluation presented a direct comparison of the results to the GPS values.

To allow comparison of the lower confidence limit of the mean to the GPS, additional samples were collected from the wells for which individual sample results had exceeded the GPS in the three initial assessment monitoring events. The additional samples were collected in March 2019, so the four sampling events fell within 1 year (May 2018 to March 2019) and provided some representation of seasonal variability in constituent concentrations.

The results for the four sampling events are summarized in **Table 1** for lithium and in **Table 2** for molybdenum. The laboratory reports for the first three events were included in the 2018 Annual Groundwater Monitoring and Corrective Action Report. The laboratory report for the March 2019 event is provided in **Appendix A**.

For each well-parameter pair that was tested, the calculated mean concentration and the lower confidence limit for the mean are shown in **Tables 1** and **2**. For lithium, the lower confidence limit for the mean was below the GPS for wells MW-303, MW-304, and MW-306. For molybdenum, both the mean and the lower confidence limit for the mean were below the GPS for wells MW-301 and MW-304. Based on these comparisons, a statistically significant exceedance of the GPS has not occurred for these wells and parameters.

3.0 ASD CONCLUSIONS

Based on the findings of the retesting and statistical evaluation, the number of well-parameter pairs for which appendix IV constituents are present at a statistically significant level exceeding the GPSs was reduced to the following:

- Lithium: MW-302, MW-307, MW-308
- Molybdenum: MW-302, MW-307, MW-308

Although the ASD reduced the number of well-parameter pairs exceeding GPSs, IPL must initiate an assessment of corrective measures based on the exceedances for the wells and parameters listed above.

4.0 REFERENCES

SCS Engineers, 2019a, 2018 Annual Groundwater Monitoring and Corrective Action Report, Burlington Generating Station, January 2019.

SCS Engineers, 2019b, Assessment Groundwater Monitoring – Statistical Evaluation, Burlington Generating Station, January 14, 2019.

U.S. Environmental Protection Agency (USEPA), 2009, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance, EPA 530-R-09-007, March 2009.

Tables

Table 1
Assessment Monitoring Results with March 2019 Retest Event - Lithium
IPL - Burlington Generating Station

Monitoring Well	Units	Groundwater Protection Standard (GPS)	Assessment Monitoring Results with Retest: 5/8/2018 and 5/9/2018	8/13/2018 and 8/14/2018	10/9/2018 and 10/10/2018	3/11/2019 and 3/12/2019	Mean	Lower Confidence Limit for Mean (α = 95%)	LCL Exceeds GPS?
MW-302	ug/L	40	65.4	61.4	57.8	59.9	61.1	58.0	**YES**
MW-303	ug/L	40	50.7	42.1	35.8	51.6	45.1	38.7	NO
MW-304	ug/L	40	63.8	34.3	82.4	35.9	54.1	34.4	NO
MW-306	ug/L	40	36.6	46.8	41.4	39.2	41.0	37.3	NO
MW-307	ug/L	40	47.8	56.1	45.4	50.7	50.0	46.1	**YES**
MW-308	ug/L	40	46.0	52.0	43.6	48.9	47.6	44.5	**YES**

created by: SCC 4/12/19
checked by: TK 4/13/19

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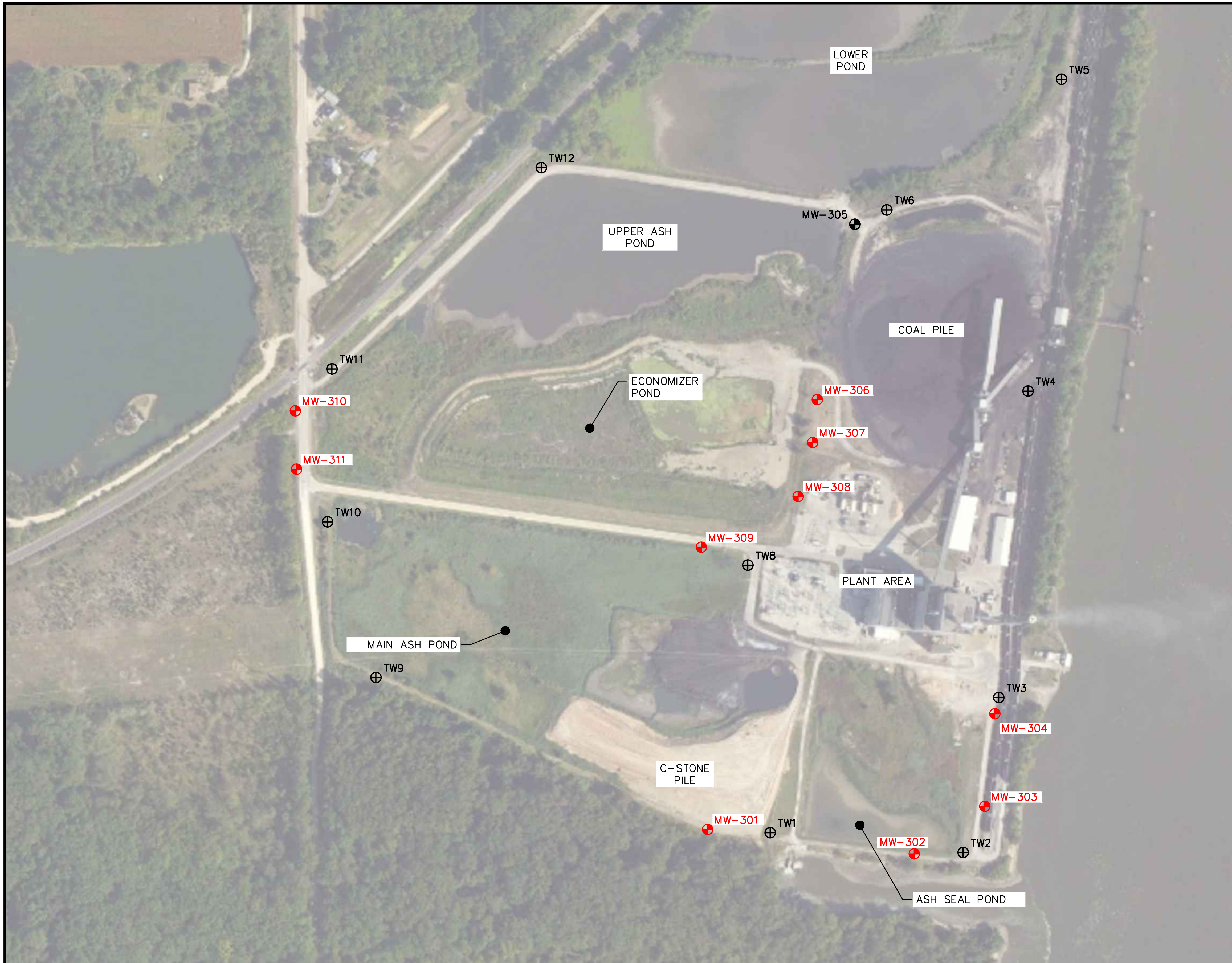
Table 2
Assessment Monitoring Results with March 2019 Retest Event - Molybbdenum
IPL - Burlington Generating Station

Monitoring Well	Units	Groundwater Protection Standard (GPS)	Assessment Monitoring Results with Retest 5/8/2018 and 5/9/2018	8/13/2018 and 8/14/2018	10/9/2018 and 10/10/2018	3/11/2019 and 3/12/2019	Mean	Lower Confidence Limit for Mean (α = 95%)	LCL Exceeds GPS?
MW-301	ug/L	100	113	81.7	120	62.7	94.4	68.0	NO
MW-302	ug/L	100	118	121	122	123	121	119	**YES**
MW-304	ug/L	100	126	74.9	113	47.4	90.3	59.9	NO
MW-307	ug/L	100	154	155	159	156	156	154	**YES**
MW-308	ug/L	100	140	140	145	135	140	137	**YES**

created by: SCC 4/12/19
checked by: TK 4/13/19

I:\25219066.00\Deliverables\1904_Assessment ASD\[Tables_1_2.xlsx]Mo

Figures



LEGEND

- EXISTING MONITORING WELL LOCATION
- TEMPORARY MONITORING WELL LOCATION (ABANDONED MARCH 2016)
- EXISTING CCR RULE MONITORING WELL

NOTES:

1. TEMPORARY WELLS TW-1 THROUGH TW-6 AND TW-8 THROUGH TW-12 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS ON OCTOBER 20 AND 21, 2015. WELL TW-7 WAS NOT INSTALLED.
2. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
3. MONITORING WELLS MW301, MW302, AND MW309-MW311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
5. TEMPORARY WELLS TW-1 THROUGH TW-6 AND TW-8 THROUGH TW-12 WERE SURVEYED BY FRENCH RENEKER-ASSOCIATES OF FRANKLIN, IA ON DECEMBER 7, 2015. THESE WELLS WERE ABANDONED ON MARCH 2, 2016.
6. MONITORING WELLS MW-301 THROUGH MW-311 WERE SURVEYED BY FRENCH-RENEKER ASSOCIATES OF FRANKLIN, IA ON MARCH 16, 2016.

N

300 0 300

SCALE: 1" = 300'

PROJECT NO.	25216066.18	DRAWN BY:	AHB/BSS
DRAWN:	04/01/16	CHECKED BY:	NK
REVISED:	01/10/19	APPROVED BY:	TK

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY
4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

SITE PLAN AND MONITORING WELL LOCATIONS

FIGURE 1

I:\25216066.00\Drawings\

11/25/2020 - Classification: Internal - ECRM7803923

Appendix A

Analytical Laboratory Report– March 2019 Retesting

Pace Analytical Services, LLC
9608 Loiret Blvd.
Lenexa, KS 66219
(913)599-5665

March 18, 2019

Meghan Blodgett
SCS Engineers
2830 Dairy Drive
Madison, WI 53718

RE: Project: BURLINGTON
Pace Project No.: 60296621

Dear Meghan Blodgett:

Enclosed are the analytical results for sample(s) received by the laboratory on March 13, 2019. 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,

Hank Kapka
hank.kapka@pacelabs.com
(913)599-5665
PM Lab Management

Enclosures

cc: Tom Karwaski, SCS Engineers
Nicole Kron, SCS Engineers
Jeff Maxted, Alliant Energy
Jess Valcheff, SCS Engeineers

CERTIFICATIONS

Project:	BURLINGTON
Pace Project No.:	60296621

Kansas Certification IDs

9608 Loiret Boulevard, Lenexa, KS 66219
Missouri Certification Number: 10090
Arkansas Drinking Water
WY STR Certification #: 2456.01
Arkansas Certification #: 18-016-0
Arkansas Drinking Water
Illinois Certification #: 004455
Iowa Certification #: 118
Kansas/NELAP Certification #: E-10116 / E10426
Louisiana Certification #: 03055
Nevada Certification #: KS000212018-1
Oklahoma Certification #: 9205/9935
Texas Certification #: T104704407-18-11
Utah Certification #: KS000212018-8
Kansas Field Laboratory Accreditation: # E-92587
Missouri Certification: 10070
Missouri Certification Number: 10090

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SAMPLE SUMMARY

Project: BURLINGTON
Pace Project No.: 60296621

Lab ID	Sample ID	Matrix	Date Collected	Date Received
60296621001	**MW-301**	Water	03/12/19 09:37	03/13/19 08:30
60296621002	**MW-302**	Water	03/12/19 10:28	03/13/19 08:30
60296621003	**MW-303**	Water	03/12/19 11:08	03/13/19 08:30
60296621004	**MW-304**	Water	03/12/19 11:41	03/13/19 08:30
60296621005	**MW-306**	Water	03/11/19 17:05	03/13/19 08:30
60296621006	**MW-307**	Water	03/11/19 16:33	03/13/19 08:30
60296621007	**MW-308**	Water	03/12/19 09:01	03/13/19 08:30
60296621008	**FIELD BLANK**	Water	03/12/19 08:00	03/13/19 08:30

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SAMPLE ANALYTE COUNT

Project: BURLINGTON
Pace Project No.: 60296621

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
60296621001	**MW-301**	EPA 6020	JGP	1	PASI-K
60296621002	**MW-302**	EPA 6010	JDE	1	PASI-K
		EPA 6020	JGP	1	PASI-K
60296621003	**MW-303**	EPA 6010	JDE	1	PASI-K
60296621004	**MW-304**	EPA 6010	JDE	1	PASI-K
		EPA 6020	JGP	1	PASI-K
60296621005	**MW-306**	EPA 6010	JDE	1	PASI-K
60296621006	**MW-307**	EPA 6010	JDE	1	PASI-K
		EPA 6020	JGP	1	PASI-K
60296621007	**MW-308**	EPA 6010	JDE	1	PASI-K
		EPA 6020	JGP	1	PASI-K
60296621008	**FIELD BLANK**	EPA 6010	JDE	1	PASI-K
		EPA 6020	JGP	1	PASI-K

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ANALYTICAL RESULTS

Project: BURLINGTON
Pace Project No.: 60296621

Sample: MW-301 **Lab ID: 60296621001** Collected: 03/12/19 09:37 Received: 03/13/19 08:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
Field Data	Analytical Method:								
Collected By	**CLIENT**				1		03/12/19 09:37		
Collected Date	**3/12/2019**				1		03/12/19 09:37		
Collected Time	**0937**				1		03/12/19 09:37		
Field pH	**6.38**	Std. Units	0.10	0.050	1		03/12/19 09:37		
Field Temperature	**12.56**	deg C	0.50	0.25	1		03/12/19 09:37		
Field Specific Conductance	**1055**	umhos/cm	1.0	1.0	1		03/12/19 09:37		
Field Oxidation Potential	**-73.1**	mV			1		03/12/19 09:37		
Oxygen, Dissolved	**2.61**	mg/L			1		03/12/19 09:37	7782-44-7	
Turbidity	**17.10**	NTU	1.0	1.0	1		03/12/19 09:37		
Groundwater Elevation	**523.38**	feet			1		03/12/19 09:37		
6020 MET ICPMS	Analytical Method: EPA 6020 Preparation Method: EPA 3010								
Molybdenum	**62.7**	ug/L	1.0	0.57	1	03/14/19 11:30	03/15/19 11:34	7439-98-7	

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ANALYTICAL RESULTS

Project: BURLINGTON
Pace Project No.: 60296621

Sample: MW-302 **Lab ID: 60296621002** Collected: 03/12/19 10:28 Received: 03/13/19 08:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
Field Data	Analytical Method:								
Collected By	**CLIENT**				1		03/12/19 10:28		
Collected Date	**3/12/2019**				1		03/12/19 10:28		
Collected Time	**1028**				1		03/12/19 10:28		
Field pH	**6.94**	Std. Units	0.10	0.050	1		03/12/19 10:28		
Field Temperature	**12.16**	deg C	0.50	0.25	1		03/12/19 10:28		
Field Specific Conductance	**792**	umhos/cm	1.0	1.0	1		03/12/19 10:28		
Field Oxidation Potential	**-70.3**	mV			1		03/12/19 10:28		
Oxygen, Dissolved	**2.68**	mg/L			1		03/12/19 10:28	7782-44-7	
Turbidity	**22.10**	NTU	1.0	1.0	1		03/12/19 10:28		
Groundwater Elevation	**522.83**	feet			1		03/12/19 10:28		
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Lithium	**59.9**	ug/L	10.0	4.6	1	03/14/19 11:30	03/15/19 17:42	7439-93-2	
6020 MET ICPMS	Analytical Method: EPA 6020 Preparation Method: EPA 3010								
Molybdenum	**123**	ug/L	1.0	0.57	1	03/14/19 11:30	03/15/19 11:35	7439-98-7	

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ANALYTICAL RESULTS

Project: BURLINGTON
Pace Project No.: 60296621

Sample: MW-303 **Lab ID: 60296621003** Collected: 03/12/19 11:08 Received: 03/13/19 08:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
Field Data	Analytical Method:								
Collected By	**CLIENT**				1		03/12/19 11:08		
Collected Date	**3/12/2019**				1		03/12/19 11:08		
Collected Time	**11:08**				1		03/12/19 11:08		
Field pH	**6.46**	Std. Units	0.10	0.050	1		03/12/19 11:08		
Field Temperature	**13.62**	deg C	0.50	0.25	1		03/12/19 11:08		
Field Specific Conductance	**549**	umhos/cm	1.0	1.0	1		03/12/19 11:08		
Field Oxidation Potential	**-68.1**	mV			1		03/12/19 11:08		
Oxygen, Dissolved	**2.38**	mg/L			1		03/12/19 11:08	7782-44-7	
Turbidity	**19.40**	NTU	1.0	1.0	1		03/12/19 11:08		
Groundwater Elevation	**522.74**	feet			1		03/12/19 11:08		
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Lithium	**51.6**	ug/L	10.0	4.6	1	03/14/19 11:30	03/15/19 17:44	7439-93-2	

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ANALYTICAL RESULTS

Project: BURLINGTON
Pace Project No.: 60296621

Sample: MW-304 **Lab ID: 60296621004** Collected: 03/12/19 11:41 Received: 03/13/19 08:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
Field Data	Analytical Method:								
Collected By	**CLIENT**				1		03/12/19 11:41		
Collected Date	**3/12/2019**				1		03/12/19 11:41		
Collected Time	**1141**				1		03/12/19 11:41		
Field pH	**6.94**	Std. Units	0.10	0.050	1		03/12/19 11:41		
Field Temperature	**13.87**	deg C	0.50	0.25	1		03/12/19 11:41		
Field Specific Conductance	**460**	umhos/cm	1.0	1.0	1		03/12/19 11:41		
Field Oxidation Potential	**-73.8**	mV			1		03/12/19 11:41		
Oxygen, Dissolved	**2.11**	mg/L			1		03/12/19 11:41	7782-44-7	
Turbidity	**9.28**	NTU	1.0	1.0	1		03/12/19 11:41		
Groundwater Elevation	**522.80**	feet			1		03/12/19 11:41		
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Lithium	**35.9**	ug/L	10.0	4.6	1	03/14/19 11:30	03/15/19 17:46	7439-93-2	
6020 MET ICPMS	Analytical Method: EPA 6020 Preparation Method: EPA 3010								
Molybdenum	**47.4**	ug/L	1.0	0.57	1	03/14/19 11:30	03/15/19 11:36	7439-98-7	

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ANALYTICAL RESULTS

Project: BURLINGTON
Pace Project No.: 60296621

Sample: MW-306 **Lab ID: 60296621005** Collected: 03/11/19 17:05 Received: 03/13/19 08:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
Field Data	Analytical Method:								
Collected By	**CLIENT**				1		03/11/19 17:05		
Collected Date	**03/11/19**				1		03/11/19 17:05		
Collected Time	**17:05:00**				1		03/11/19 17:05		
Field pH	**6.27**	Std. Units	0.10	0.050	1		03/11/19 17:05		
Field Temperature	**14.27**	deg C	0.50	0.25	1		03/11/19 17:05		
Field Specific Conductance	**343**	umhos/cm	1.0	1.0	1		03/11/19 17:05		
Field Oxidation Potential	**-88.9**	mV			1		03/11/19 17:05		
Oxygen, Dissolved	**0.80**	mg/L			1		03/11/19 17:05	7782-44-7	
Turbidity	**0.56**	NTU	1.0	1.0	1		03/11/19 17:05		
Groundwater Elevation	**523.21**	feet			1		03/11/19 17:05		
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Lithium	**39.2**	ug/L	10.0	4.6	1	03/14/19 11:30	03/15/19 17:48	7439-93-2	

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ANALYTICAL RESULTS

Project: BURLINGTON
Pace Project No.: 60296621

Sample: MW-307 **Lab ID: 60296621006** Collected: 03/11/19 16:33 Received: 03/13/19 08:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
Field Data	Analytical Method:								
Collected By	**CLIENT**				1		03/11/19 16:33		
Collected Date	**3/11/2019**				1		03/11/19 16:33		
Collected Time	**1633**				1		03/11/19 16:33		
Field pH	**9.71**	Std. Units	0.10	0.050	1		03/11/19 16:33		
Field Temperature	**14.36**	deg C	0.50	0.25	1		03/11/19 16:33		
Field Specific Conductance	**367**	umhos/cm	1.0	1.0	1		03/11/19 16:33		
Field Oxidation Potential	**-78.3**	mV			1		03/11/19 16:33		
Oxygen, Dissolved	**1.07**	mg/L			1		03/11/19 16:33	7782-44-7	
Turbidity	**1.05**	NTU	1.0	1.0	1		03/11/19 16:33		
Groundwater Elevation	**523.49**	feet			1		03/11/19 16:33		
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Lithium	**50.7**	ug/L	10.0	4.6	1	03/14/19 11:30	03/15/19 17:51	7439-93-2	
6020 MET ICPMS	Analytical Method: EPA 6020 Preparation Method: EPA 3010								
Molybdenum	**156**	ug/L	1.0	0.57	1	03/14/19 11:30	03/15/19 11:40	7439-98-7	

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ANALYTICAL RESULTS

Project: BURLINGTON
Pace Project No.: 60296621

Sample: MW-308 **Lab ID: 60296621007** Collected: 03/12/19 09:01 Received: 03/13/19 08:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
Field Data	Analytical Method:								
Collected By	**CLIENT**				1		03/12/19 09:01		
Collected Date	**03/12/19**				1		03/12/19 09:01		
Collected Time	**09:01:00**				1		03/12/19 09:01		
Field pH	**7.72**	Std. Units	0.10	0.050	1		03/12/19 09:01		
Field Temperature	**14.06**	deg C	0.50	0.25	1		03/12/19 09:01		
Field Specific Conductance	**500**	umhos/cm	1.0	1.0	1		03/12/19 09:01		
Field Oxidation Potential	**-60.7**	mV			1		03/12/19 09:01		
Oxygen, Dissolved	**2.57**	mg/L			1		03/12/19 09:01	7782-44-7	
Turbidity	**1.68**	NTU	1.0	1.0	1		03/12/19 09:01		
Groundwater Elevation	**523.13**	feet			1		03/12/19 09:01		
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Lithium	**48.9**	ug/L	10.0	4.6	1	03/14/19 11:30	03/15/19 17:53	7439-93-2	
6020 MET ICPMS	Analytical Method: EPA 6020 Preparation Method: EPA 3010								
Molybdenum	**135**	ug/L	1.0	0.57	1	03/14/19 11:30	03/15/19 11:41	7439-98-7	

REPORT OF LABORATORY ANALYSIS

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ANALYTICAL RESULTS

Project: BURLINGTON
Pace Project No.: 60296621

Sample: FIELD BLANK **Lab ID: 60296621008** Collected: 03/12/19 08:00 Received: 03/13/19 08:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Lithium	**<4.6**	ug/L	10.0	4.6	1	03/14/19 11:30	03/15/19 17:55	7439-93-2	
6020 MET ICPMS	Analytical Method: EPA 6020 Preparation Method: EPA 3010								
Molybdenum	**<0.57**	ug/L	1.0	0.57	1	03/14/19 11:30	03/15/19 12:00	7439-98-7	

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QUALITY CONTROL DATA

Project: BURLINGTON
Pace Project No.: 60296621

QC Batch: 573639 Analysis Method: EPA 6010
QC Batch Method: EPA 3010 Analysis Description: 6010 MET
Associated Lab Samples: 60296621002, 60296621003, 60296621004, 60296621005, 60296621006, 60296621007, 60296621008

METHOD BLANK: 2352852 Matrix: Water
Associated Lab Samples: 60296621002, 60296621003, 60296621004, 60296621005, 60296621006, 60296621007, 60296621008

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Lithium	ug/L	<4.6	10.0	4.6	03/15/19 17:29	

LABORATORY CONTROL SAMPLE: 2352853

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Lithium	ug/L	1000	989	99	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2352854 2352855

Parameter	Units	60296423001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Lithium	ug/L	30.8	1000	1000	1050	1050	102	102	75-125	0	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.

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QUALITY CONTROL DATA

Project: BURLINGTON
Pace Project No.: 60296621

QC Batch: 573643 Analysis Method: EPA 6020
QC Batch Method: EPA 3010 Analysis Description: 6020 MET
Associated Lab Samples: 60296621001, 60296621002, 60296621004, 60296621006, 60296621007, 60296621008

METHOD BLANK: 2352876 Matrix: Water
Associated Lab Samples: 60296621001, 60296621002, 60296621004, 60296621006, 60296621007, 60296621008

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Molybdenum	ug/L	<0.57	1.0	0.57	03/15/19 11:25	

LABORATORY CONTROL SAMPLE: 2352877

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Molybdenum	ug/L	40	36.9	92	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2352878 2352879

Parameter	Units	60296495004 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Molybdenum	ug/L	ND	40	40	38.7	36.9	96	92	75-125	5	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.

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QUALIFIERS

Project:	BURLINGTON
Pace Project No.:	60296621

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 - The lowest concentration value that meets project requirements for quantitative data with known precision and bias for a specific analyte in a specific matrix.

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.

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-K   Pace Analytical Services - Kansas City

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QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: BURLINGTON
Pace Project No.: 60296621

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
60296621001	**MW-301**		573633		
60296621002	**MW-302**		573633		
60296621003	**MW-303**		573633		
60296621004	**MW-304**		573633		
60296621005	**MW-306**		573633		
60296621006	**MW-307**		573633		
60296621007	**MW-308**		573633		
60296621002	**MW-302**	EPA 3010	573639	EPA 6010	573741
60296621003	**MW-303**	EPA 3010	573639	EPA 6010	573741
60296621004	**MW-304**	EPA 3010	573639	EPA 6010	573741
60296621005	**MW-306**	EPA 3010	573639	EPA 6010	573741
60296621006	**MW-307**	EPA 3010	573639	EPA 6010	573741
60296621007	**MW-308**	EPA 3010	573639	EPA 6010	573741
60296621008	**FIELD BLANK**	EPA 3010	573639	EPA 6010	573741
60296621001	**MW-301**	EPA 3010	573643	EPA 6020	573737
60296621002	**MW-302**	EPA 3010	573643	EPA 6020	573737
60296621004	**MW-304**	EPA 3010	573643	EPA 6020	573737
60296621006	**MW-307**	EPA 3010	573643	EPA 6020	573737
60296621007	**MW-308**	EPA 3010	573643	EPA 6020	573737
60296621008	**FIELD BLANK**	EPA 3010	573643	EPA 6020	573737

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Sample Condition Upon Receipt

WO# : 60296621

60296621

Client Name: SCS

Courier: FedEx ☑ UPS ☐ VIA ☐ Clay ☐ PEX ☐ ECI ☐ Pace ☐ Xroads ☐ Client ☐ Other ☐

Tracking #: 4506 2681 8782 Pace Shipping Label Used? Yes ☑ No ☐

Custody Seal on Cooler/Box Present: Yes ☑ No ☐ Seals intact: Yes ☑ No ☐

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

Thermometer Used: T-298 **Type of Ice:** (Wet) Blue None

Cooler Temperature (°C): **As-read** 4.7 **Corr. Factor** -0.1 **Corrected** 4.6

Date and initials of person examining contents: 3/13/19 [initials]

Temperature should be above freezing to 6°C

Chain of Custody present:	☑Yes ☐No ☐N/A	
Chain of Custody relinquished:	☑Yes ☐No ☐N/A	
Samples arrived within holding time:	☑Yes ☐No ☐N/A	
Short Hold Time analyses (<72hr):	☐Yes ☑No ☐N/A	
Rush Turn Around Time requested:	☐Yes ☑No ☐N/A	
Sufficient volume:	☑Yes ☐No ☐N/A	
Correct containers used:	☑Yes ☐No ☐N/A	
Pace containers used:	☑Yes ☐No ☐N/A	
Containers intact:	☑Yes ☐No ☐N/A	
Unpreserved 5035A / TX1005/1006 soils frozen in 48hrs?	☐Yes ☐No ☑N/A	
Filtered volume received for dissolved tests?	☐Yes ☐No ☑N/A	
Sample labels match COC: Date / time / ID / analyses	☑Yes ☐No ☐N/A	
Samples contain multiple phases? Matrix: wt	☐Yes ☑No ☐N/A	
Containers requiring pH preservation in compliance? (HNO_3, H_2SO_4, HCl<2; NaOH>9 Sulfide, NaOH>10 Cyanide) (Exceptions: VOA, Micro, O&G, KS TPH, OK-DRO)	☐Yes ☐No ☑N/A	List sample IDs, volumes, lot #'s of preservative and the date/time added.
Cyanide water sample checks: Lead acetate strip turns dark? (Record only) Potassium iodide test strip turns blue/purple? (Preserve)	 ☐Yes ☐No ☐Yes ☐No	
Trip Blank present:	☑Yes ☐No ☐N/A	
Headspace in VOA vials (>6mm):	~~☑Yes~~ ☐No (☑N/A) [initials] 3/13/19	
Samples from USDA Regulated Area: State:	☐Yes ☐No ☑N/A	
Additional labels attached to 5035A / TX1005 vials in the field?	☐Yes ☐No ☑N/A	

Client Notification/ Resolution: Copy COC to Client? Y / N Field Data Required? Y / N

Person Contacted: ____________ Date/Time: ____________

Comments/ Resolution: ____________

Project Manager Review: Hank 04:32 pm,Mar 13,2019 Kapka Date: ____________

F-KS-C-003-Rev.11, February 28, 2018

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www.pacelabs.com

CHAIN-OF-CUSTODY / Analytical Request Document

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

Page: of

Section A
Required Client Information:

Company:	SCS Engineers
Address:	2830 Dairy Drive
	Madison WI 53718
Email To:	mblodgett@scsengineers.com
Phone:	608-216-7362 Fax:
Requested Due Date/TAT:	

Section B
Required Project Information:

Report To:	Meghan Blodgett
Copy To:	Tom Karwaski
Purchase Order No.:	
Project Name:	Burlington
Project Number:	25216066.18

Section C
Invoice Information:

Attention:	Meghan Blodgett/Jess Valcheff
Company Name:	SCS Engineers
Address:	
Pace Quote Reference:	
Pace Project Manager:	Trudy Gipson 913-563-1405
Pace Profile #:	6696 Line 2

REGULATORY AGENCY

☐ NPDES ☐ GROUND WATER ☐ DRINKING WATER
☐ UST ☐ RCRA ☐ OTHER ______

Site Location STATE: IA

Section D Required Client Information

Valid Matrix Codes

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 (A-Z, 0-9 / ,-) Sample IDs MUST BE UNIQUE

Requested Analysis Filtered (Y/N): N N N

Pace Project No./ Lab I.D.: 60296621

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED COMPOSITE START DATE	COMPOSITE START TIME	COMPOSITE END/GRAB DATE	COMPOSITE END/GRAB TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Unpreserved	H_2SO_4	HNO_3	HCl	NaOH	$Na_2S_2O_3$	Methanol	Other	Analysis Test (Y/N)	6010; Li	6020; Mo		Residual Chlorine (Y/N)	Pace Project No./ Lab I.D.
1	MW-301	WT	G	xxx	xxx	3/12	0937		1			1								X	BP3N		001
2	MW-302	WT	G	xxx	xxx	3/12	1028		1			1							X	X	↓		002
3	MW-303	WT	G	xxx	xxx	3/12	1108		1			1							X				003
4	MW-304	WT	G	xxx	xxx	3/12	1141		1			1							X	X	↓		004
5																							
6	MW-306	WT	G	xxx	xxx	3/11	1705		1			1							X		BP3N		005
7	MW-307	WT	G	xxx	xxx	3/11	1633		1			1							X	X	↓		006
8	MW-308	WT	G	xxx	xxx	3/12	0901		1			1							X	X	↓		007
9	Field Blank					3/12	0800		1	1									X	X	BP3U		008
10																							
11																							
12																							

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	SAMPLE CONDITIONS			
Ship To: 9608 Loiret Boulevard, Lenexa, KS 66219	Nick Schemmel / SCS	3/12	1310	[signature] / Pace	3/13/19	0830	4.6	Y	Y	Y
* Sb-As-Ba-Be-Cd-Co-Cr-Pb-Mo-Se-Tl										
							Temp in °C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER:

SIGNATURE of SAMPLER: **DATE Signed (MM/DD/YY):**

*Important Note: By signing this form you are accepting Pace's NET 30 day payment terms and agreeing to late charges of 1.5% per month for any invoices not paid within 30 days.

F-ALL-Q-020rev.07, 15-Feb-2007

Appendix C

Demonstration of Need for ACM Deadline Extension

SCS ENGINEERS
Environmental Consultants & Contractors

July 10, 2019
File No. 25218201.00

Ms. Robin Nelson
Interstate Power and Light Company
4282 Sullivan Slough Road
Burlington, IA 52601

Subject: Demonstration of Need for Deadline Extension
Assessment of Corrective Measures
Burlington Generating Station, Burlington, Iowa

Dear Ms. Nelson:

In accordance with 40 CFR 257.96(a), Interstate Power and Light Company (IPL) has initiated an Assessment of Corrective Measures (ACM) for the Burlington Generating Station. The ACM was initiated on April 15, 2019, in response to detections of constituents in Appendix IV to 40 CFR Part 257 at statistically significant levels above the groundwater protection standards (GPS) established under 40 CFR 257.95(h). As allowed under 40 CFR 257.96(a), this letter provides a demonstration that additional time beyond the 90-day deadline is needed to complete the ACM, and that the deadline may be extended by 60 days. Therefore, the ACM must be completed by September 13, 2019.

Demonstration of Need for Additional Time

Additional time is needed to complete the ACM in order to investigate the nature and extent of downgradient groundwater impacts and consider that information in preparing the ACM. The additional information obtained through further investigation of site conditions is important to the selection of suitable corrective measures and the evaluation of those corrective measures in meeting the requirements and objectives outlined in 40 CFR 257.96(c). Specifically, additional data about the nature and extent of groundwater impacts is needed to determine the current level of risk, evaluate the reduction of risk provided, and evaluate the implementation of potential corrective measures.

In January 2019, prior to initiating an ACM in April 2019, IPL began the process of designing, permitting, installing, and sampling additional groundwater monitoring wells to investigate the nature and extent of these constituents in groundwater, in accordance with 40 CFR 257.95(g)(1).

The following factors contributed to delays in the installation and sampling of the new wells, which in turn created the need for the extension of the ACM deadline by up to 60 days as allowed under 40 CFR 257.96(a):

- Permitting for the new wells included Federal, state, and local permit reviews related to floodplains, wetlands, and sovereign lands, which significantly delayed well installation.

- Drilling subcontractor schedules caused additional delays due to limited subcontractor availability and Iowa drilling licensing requirements.

Additional information regarding the nature and extent of groundwater impacts will provide further understanding of existing risks associated with the groundwater impacts identified at the Burlington Generating Station, which provides the basis for evaluating potential corrective measures as required under 40 CFR 257.96. While evaluation of the nature and extent of impacts may continue in parallel with the ACM and selection of remedy, extending the ACM deadline as allowed under the coal combustion residuals (CCR) rule will allow for the consideration of additional information and provide for a more complete ACM. Thus, the 60-day extension is needed.

As required by 40 CFR 257.96(a), a professional engineer's certification of the accuracy of this demonstration is enclosed.

PE Certification

As required by 40 CFR 257.96, I, Eric J. Nelson, hereby certify that this demonstration of need for the 60-day extension of the deadline for completing an Assessment of Corrective Measures is accurate. I am a duly licensed Professional Engineer under the laws of the State of Iowa.

7/10/2019

(signature) (date)

Eric J. Nelson

(printed or typed name)

License number 23136

My license renewal date is December 31, 2020.

Pages or sheets covered by this seal:

ACM - Demonstration of Need for Deadline Extension

Burlington Generating Station

Sincerely,

Eric J. Nelson, PE	Thomas J. Karwoski
Project Director	Senior Project Manager
SCS Engineers	SCS Engineers

EJN/AJR/SC

cc: Robert Huschak, Interstate Power and Light Company
Jeff Maxted, Alliant Energy

I:\25218201.00\Correspondence\Client\ACM Extension\190710_Nelson_BGS_ACM Ext_PE_Certification_Letter.docx

B4 Sampling and Analysis Plan

SCS ENGINEERS







Groundwater Sampling and Analysis Plan

Burlington Generating Station
Burlington, Iowa

Prepared for:

Interstate Power and Light Company

4902 N Biltmore Lane
Madison, Wisconsin 53707

Prepared by:

SCS ENGINEERS
2830 Dairy Drive
Madison, Wisconsin 53718-6751
(608) 224-2830

October 2017
File No. 25216066.17

Offices Nationwide
www.scsengineers.com

Groundwater Sampling and Analysis Plan
Burlington Generating Station
Burlington, Iowa

Prepared for:

Interstate Power and Light Company
4902 N Biltmore Lane
Madison, Wisconsin 53707

Prepared by:

SCS ENGINEERS
2830 Dairy Drive
Madison, Wisconsin 53718-6751
(608) 224-2830

October 2017
File No. 25216066.17

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I:\25216066.00\Deliverables\Sampling & Analysis Plan\Final for Operating Record\Burlington_SAP_171011_Final.doc

SIGNATURES PAGE

Meghan Blodgett
Hydrogeologist
SCS ENGINEERS

Thomas J. Karwoski
Project Manager
SCS ENGINEERS

1.0 INTRODUCTION

This Groundwater Sampling Plan (plan) summarizes groundwater sampling and analysis procedures for the Burlington Generating Station, a generating station with coal combustion residuals (CCR) settling ponds located in Burlington, Iowa (**Figure 1**). Groundwater sampling at this site is performed to satisfy sampling requirements under United States Environmental Protection Agency (USEPA) Rule 40 CFR Part 257.50-107 (CCR rule sampling). This plan was prepared in accordance with the requirements of 40 CFR Part 257.93(a).

2.0 SAMPLING EVENTS AND PARAMETERS

Groundwater monitoring under the federal program includes semiannual sampling events beginning in October 2017. All samples collected under the CCR rule sampling program are to be unfiltered (total analysis).

A list of the locations at which water level measurements and samples will be collected is included in **Table 1**. This table includes the parameters that may be analyzed at each sampling location. Sampling point locations are shown on **Figure 2**.

3.0 FIELD METHODS

3.1 WATER LEVEL MEASUREMENTS

Depth to water and total well depth will be recorded at each monitoring well immediately prior to purging. These measurements should be taken from the top of the polyvinyl chloride (PVC) well casing. During each sampling event, depths to groundwater at all wells must be measured within a period of time short enough to avoid temporal variations in groundwater flow which could preclude accurate determination of groundwater flow rate and direction.

3.2 WELL PURGING – LOW-FLOW METHOD

Wells will be sampled using low-flow sampling techniques, as documented in USEPA publication EPA/540/S-95/504. All site wells have dedicated WellWizard ™ sampling systems for this purpose. These dedicated pump systems will be used for well purging and for sample collection.

After the initial water level measurement, the well will be purged with a consistent flow of 1 liter per minute (L/min) or less. The water level should remain stable or stabilize during the purging. If the level does not stabilize and continues to drop, the flow rate will be reduced. If the level does not stabilize with a flow rate of 50 milliliters per minute (mL/min), the well will be purged according to the procedure in **Section 3.3**. The purge rate will be measured using a calibrated device and timer, and recorded.

Purge water should be monitored until three consecutive readings, taken approximately 2 minutes or 0.5 well volumes apart, are stabilized within the provided ranges for the following parameters:

Parameter	Range
pH[1,2]	+/- 0.1 unit
Specific Conductance[1,2]	+/- 3%
Dissolved Oxygen[1,2]	+/- 10%
Oxidation/Reduction Potential[1,2]	+/- 10 millivolts
Temperature[2]	+/- 3%
Turbidity[1,2] (Required if collecting non-filtered metals samples. Recommended otherwise.)	+/- 10% for values greater than 5 NTU. If three turbidity values are less than 5 NTU, consider the values as stabilized.

References: (1): USEPA Publication EPA/540/S-95/504 and (2): USEPA Region 1 Low-Stress (Low-Flow) SOP, Revision Number 3, Revised January 19, 2010.

Measurements will be collected using a portable meter and recorded on a Groundwater Sampling Log (**Appendix A**). All parameters except turbidity must be obtained using a flow-through cell. Samples for turbidity measurements will be obtained before water enters the flow-through cell.

Meter calibration will be performed according to the manufacturer's instructions and will be documented in the field book. Observations of sample odor and color will be recorded. Visual observations of turbidity may be recorded in addition to instrument readings.

Once the readings have stabilized, which indicates that stagnant water in the well has been replaced with formation water, the well will be ready for groundwater sampling from the discharge.

3.3 WELL PURGING – IF STABLE WATER LEVEL CANNOT BE ACHIEVED

If a stable water level cannot be achieved in a well with low-flow purging methods, in a well where low-flow sampling is the intended sampling method, the well will be purged using the dedicated pump. The well will then be allowed to recover sufficiently so that the required sample volume may be collected. The sample will be collected using the dedicated low-flow pump. The pumping rate should be set as slow as practical in order to minimize sample turbidity.

If this method is used, the indicator field parameters listed in **Section 3.2** will be recorded but stability is not required. The depth to water before sample collection will be recorded.

3.4 SAMPLING PROTOCOL

3.4.1 Monitoring Wells – Low-Flow Method

After each well is determined to have stabilized (see **Section 3.2**), samples will be collected using the dedicated bladder pump. Disposable chemical-resistant (e.g., nitrile) gloves will be worn during sampling and will be changed between sampling points.

All samples will be labeled with the sample ID (monitoring well number), site name, project number, time and date of collection, analytical parameters, preservative, and the initials of the sampler. The laboratory will provide instructions regarding the preservation techniques required for each analysis. The laboratory will provide any required temperature and/or trip blanks, and will provide water and sample containers for field blanks.

3.4.2 Monitoring Wells – Low-Flow Method in Slow-Recovering Wells

At wells purged using the procedure described in **Section 3.2**, samples will be collected using the dedicated bladder pump after the well has recovered sufficiently for the required sample volume to be collected. The pumping rate during sampling will be set as low as practical in order to minimize sample turbidity. Disposable chemical-resistant (e.g., nitrile) gloves will be worn during sampling and will be changed between sampling points.

All samples will be labeled with the sample ID (monitoring well number), site name, project number, time and date of collection, analytical parameters, preservative, and the initials of the sampler. The laboratory will provide instructions regarding the preservation techniques required for each analysis. The laboratory will provide any required temperature and/or trip blanks, and will provide water and sample containers for field blanks.

3.4.3 Quality Assurance and Quality Control

A Field Blank sample will be collected during each sampling event using distilled or deionized water and sample containers provided by the laboratory. If applicable, the Field Blank bottles will be filled in an area of the site where the risk of sample contamination from CCR handling activities appears to be the greatest (e.g., next to a monitoring well, adjacent to or downwind of an active CCR handling area). The location where the Field Blank bottles were filled will be recorded in the field notes.

3.4.4 Sample Containers

Sample containers will be provided by the laboratory contractor for the sample analysis. Containers for samples that require preservation will be pre-preserved by the laboratory. The laboratory will provide sample containers for the collection of quality control samples.

3.4.5 Sample Preservation

Samples will be preserved as required for the analytical methods being used. The laboratory will provide instructions and sample containers pre-filled with preservative chemicals, if required. All samples will be kept on ice from the time of collection until they are submitted to the laboratory.

3.4.6 Sample Shipment

Samples for all parameters except radium will be packed in coolers with ice and will be shipped to the laboratory using a method that ensures delivery within required temperature limits. Radium samples do not require ice for shipping. Typically, samples will be shipped for next-day delivery using a courier service or a shipping company (e.g., FedEx or UPS).

3.5 EQUIPMENT DECONTAMINATION

Equipment that is not dedicated to a single well (e.g., water level measurement tape or non-dedicated pump) will be decontaminated between monitoring points. Decontamination will consist of cleaning with water and nonphosphate detergent (i.e., Alconox™ or equivalent), followed by a double-rinse with distilled water.

4.0 ANALYTICAL METHODS

Laboratory sample analysis will be performed using the following methods. Other methods may be substituted provided the Limit of Detection of the new method is lower than the regulatory standard(s) to which the results will be compared.

- Total Metals (except mercury) – EPA 6010 or 6020
- Mercury – EPA 7470
- Anions – EPA 9056 or EPA 300.0
- Total Dissolved Solids – SM 2540C
- Radium 226 – EPA 903.1
- Radium 228 – EPA 904.0

4.1 ANALYTICAL QUALITY ASSURANCE/QUALITY CONTROL

Samples for laboratory analysis will be submitted only to a laboratory that is certified for the methods listed in **Section 4.0**. The laboratory will have established Quality Assurance/Quality Control (QA/QC) procedures that conform to industry standards.

5.0 DOCUMENTATION

5.1 FIELD DOCUMENTATION

Water levels, purge volumes, sample times, field parameters, and general well condition information will be recorded on Groundwater Sampling Log forms (**Appendix A**).

5.2 CHAIN OF CUSTODY

Chain of Custody forms will be supplied by the laboratory and completed in the field by the sampler. An example Chain of Custody form is included in **Appendix B**. At a minimum, Chain of Custody forms will include:

- Sample IDs, date and time of sample collection, required analyses for each sample, and sample preservative (if applicable)
- Site name and project number
- Sampler's name and company
- Laboratory name and address
- Signature of person relinquishing samples for shipping

6.0 STATISTICAL ANALYSIS

Groundwater monitoring data for the Burlington Generating Station CCR units will be evaluated in accordance with 40 CFR 257.93(f)(3). The procedures to be followed for statistical analysis of groundwater monitoring data are included in **Appendix C**.

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TABLE 1

Sampling Points and Parameters – CCR Rule Sampling Program

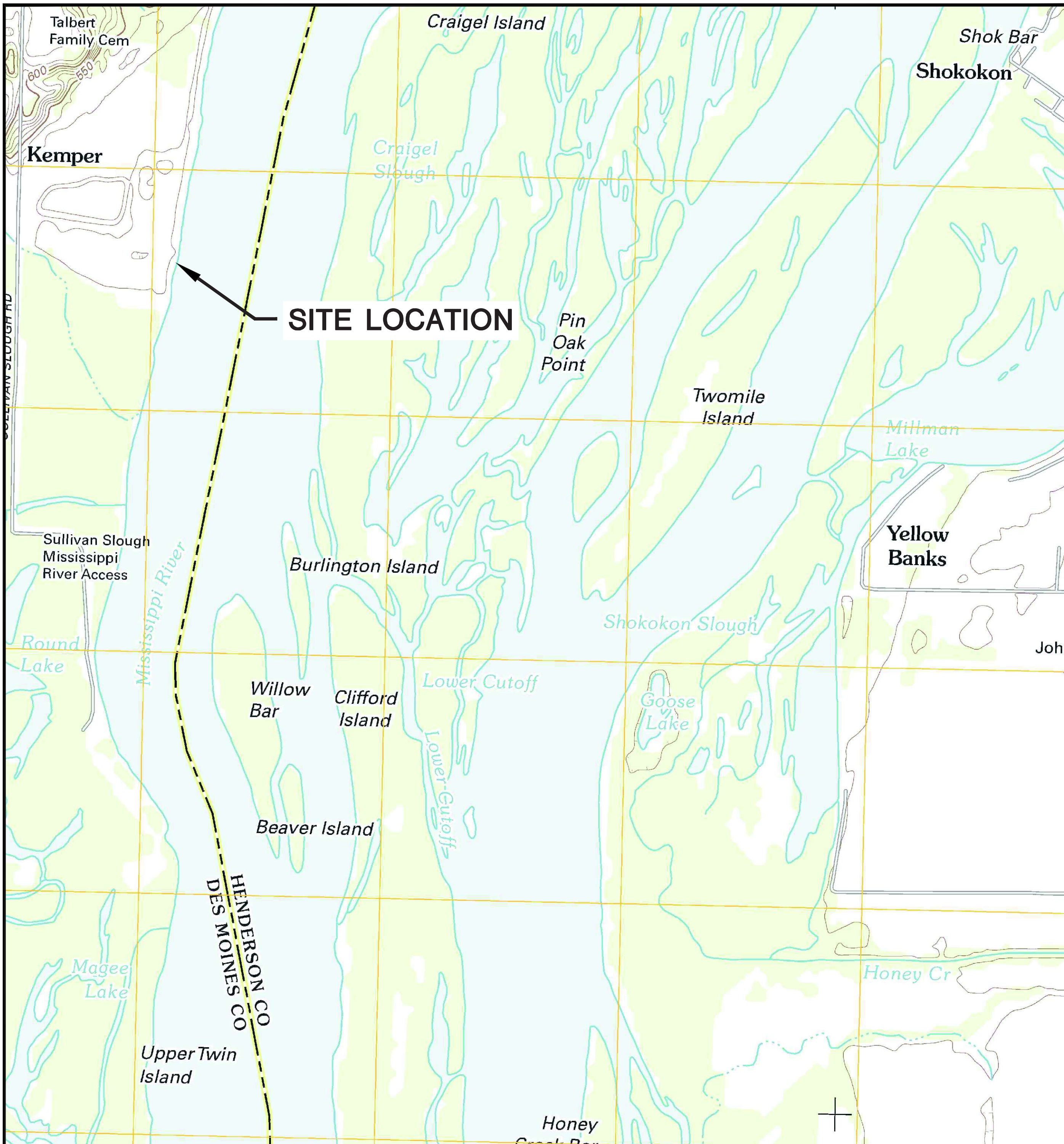
Table 1. Sampling Points and Parameters - CCR Rule Sampling Program
Groundwater Monitoring - Burlington Generating Station / SCS Engineers Project #25216066.17

	Parameter	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306	MW-307	MW-308	MW-309	MW-310	MW-311	Field Blank
Appendix III Parameters (Detection Monitoring)	Boron	X	X	X	X	X	X	X	X	X	X	X	X
	Calcium	X	X	X	X	X	X	X	X	X	X	X	X
	Chloride	X	X	X	X	X	X	X	X	X	X	X	X
	Fluoride	X	X	X	X	X	X	X	X	X	X	X	X
	pH	X	X	X	X	X	X	X	X	X	X	X	X
	Sulfate	X	X	X	X	X	X	X	X	X	X	X	X
	TDS	X	X	X	X	X	X	X	X	X	X	X	X
Appendix IV Parameters (Assessment Monitoring)	Antimony	X	X	X	X	X	X	X	X	X	X	X	X
	Arsenic	X	X	X	X	X	X	X	X	X	X	X	X
	Barium	X	X	X	X	X	X	X	X	X	X	X	X
	Beryllium	X	X	X	X	X	X	X	X	X	X	X	X
	Cadmium	X	X	X	X	X	X	X	X	X	X	X	X
	Chromium	X	X	X	X	X	X	X	X	X	X	X	X
	Cobalt	X	X	X	X	X	X	X	X	X	X	X	X
	Fluoride	X	X	X	X	X	X	X	X	X	X	X	X
	Lead	X	X	X	X	X	X	X	X	X	X	X	X
	Lithium	X	X	X	X	X	X	X	X	X	X	X	X
	Mercury	X	X	X	X	X	X	X	X	X	X	X	X
	Molybdenum	X	X	X	X	X	X	X	X	X	X	X	X
	Selenium	X	X	X	X	X	X	X	X	X	X	X	X
	Thallium	X	X	X	X	X	X	X	X	X	X	X	X
	Radium	X	X	X	X	X	X	X	X	X	X	X	X
CCR Rule Field Parameters	Groundwater Elevation	X	X	X	X	X	X	X	X	X	X	X	
	pH	X	X	X	X	X	X	X	X	X	X	X	
Low-Flow Sampling Field Parameters	Well Depth	X	X	X	X	X	X	X	X	X	X	X	
	Specific Conductance	X	X	X	X	X	X	X	X	X	X	X	
	Dissolved Oxygen	X	X	X	X	X	X	X	X	X	X	X	
	ORP	X	X	X	X	X	X	X	X	X	X	X	
	Temperature	X	X	X	X	X	X	X	X	X	X	X	
	Turbidity	X	X	X	X	X	X	X	X	X	X	X	
	Color	X	X	X	X	X	X	X	X	X	X	X	
	Odor	X	X	X	X	X	X	X	X	X	X	X	

Notes: All samples are unfiltered (total).

I:\25216066.00\Deliverables\Sampling & Analysis Plan\Final for Operating Record\[Table_1_BGS_CCR_Rule_Sampling.xls]Sheet1

FIGURES



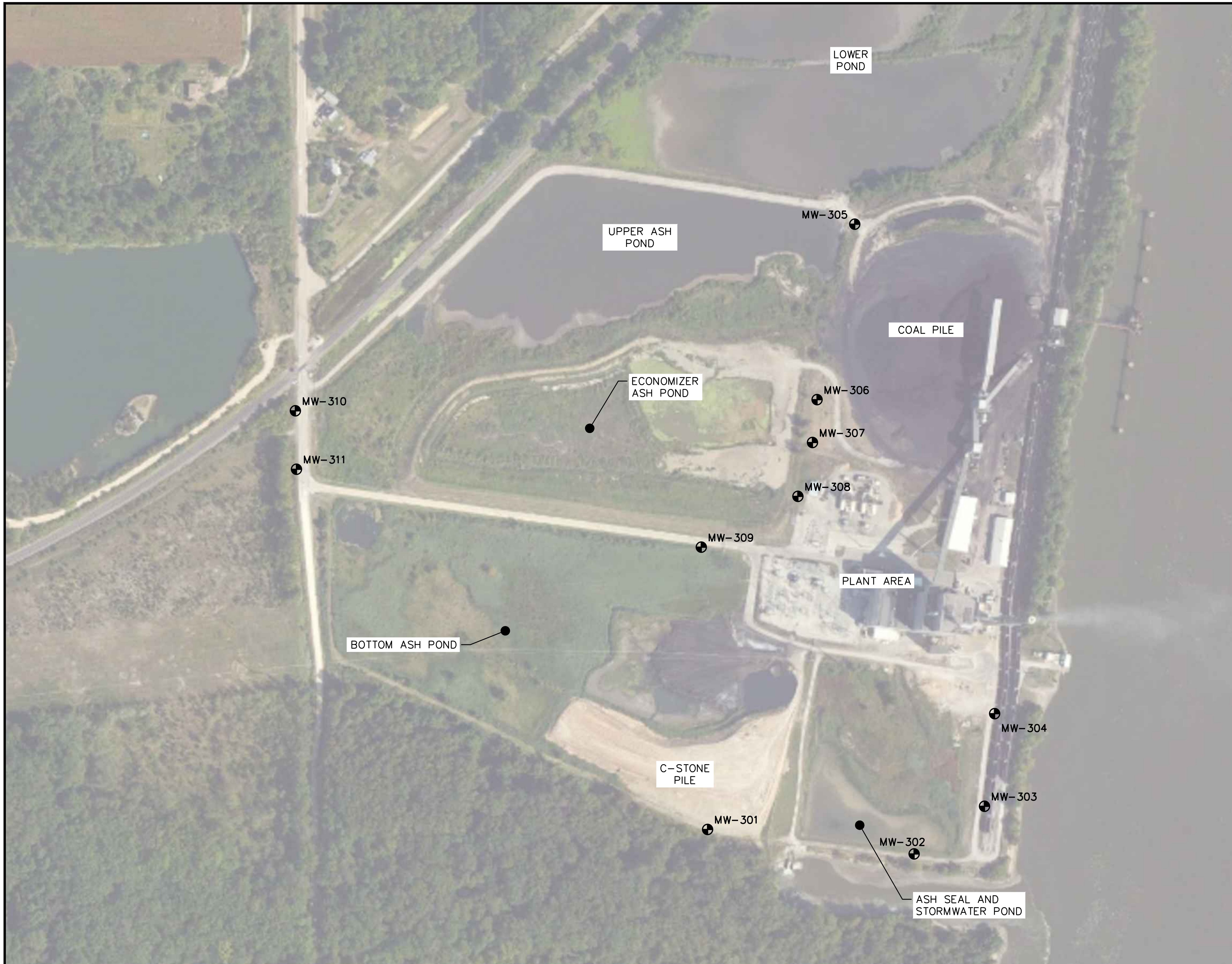
N

LOMAX QUADRANGLE
IOWA–ILLINOIS
7.5 MINUTE SERIES (TOPOGRAPHIC)
2012
SCALE: 1" = 2,000'

CLIENT	SITE	
ALLIANT ENERGY 4902 N. BILTMORE LANE, #1000 MADISON, WI 53718	ALLIANT ENERGY BURLINGTON GENERATING STATION BURLINGTON, IOWA	SITE LOCATION MAP

				ENGINEER	FIGURE
PROJECT NO.	25215135.80	DRAWN BY:	AHB	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	1
DRAWN:	05/29/15	CHECKED BY:	KAK		
REVISED:	04/01/16	APPROVED BY:			

I:\25215135\Drawings\BGS\Site Loc.dwg, 4/1/2016 1:29:58 PM



LEGEND

EXISTING MONITORING WELL LOCATION

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW301, MW302, AND MW309-MW311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-301 THROUGH MW-311 WERE SURVEYED BY FRENCH-RENEKER ASSOCIATES OF FRANKLIN, IA ON MARCH 16, 2016.

N

300 0 300

SCALE: 1" = 300'

PROJECT NO.	25216066.00	DRAWN BY:	AHB
DRAWN:	04/01/16	CHECKED BY:	MDB
REVISED:	09/18/17	APPROVED BY:	

ENGINEER: SCS ENGINEERS, 2830 DAIRY DRIVE MADISON, WI 53718-6751, PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY, 4902 N. BILTMORE LANE, #1000, MADISON, WI 53718

SITE: ALLIANT ENERGY, BURLINGTON GENERATING STATION, BURLINGTON, IOWA

SITE PLAN AND MONITORING WELL LOCATIONS

FIGURE 2

I:\25216066.00\Drawings\Monitoring Well Locations.dwg, 9/18/2017 3:08:24 PM

APPENDIX A

Low-Flow Groundwater Sampling Log

Environmental Consultants
and Contractors

2830 Dairy Drive
Madison, WI 53718-6751

608 224-2830
FAX 608 224-2839
www.scsengineers.com

SCS ENGINEERS

Groundwater Sampling Log

Project No. ____________________ **Site** ____________________

Well No. ____________________ **Date** ____________________

Well Depth ____________________ **Sampling Device** ____________________

Water Level ____________________ **Other Info.** ____________________

Purge Volume ____________________ **Pumping Rate** ____________________

Sampling Personnel ____________________

Color/Odor ____________________

Time	Water Level	Temp.	pH	DO (mg/L)	Conductivity (µs/cm)	ORP	Turbidity	Notes
Stability Requirements:		+/- 3%	+/- 0.1 unit	±/- 10%	+/- 3%	+/- 10mV	+/- 10% or 3 readings <5 NTU	

Type of Samples Collected: ____________________

Additional Notes: ____________________

Information: 2 in = 617 ml/ft, 4 in = 2,470 ml/ft: $Vol_{cyl} = \pi r^2 h$, $Vol_{sphere} = 4/3\pi\ r^3$

APPENDIX B

Example Chain of Custody

(Please Print Clearly)

Company Name:	SCS Engineers
Branch/Location:	Madison, WI
Project Contact:	Tom Karwoski
Phone:	(608) 224-2830
Project Number:	25216066.17
Project Name:	IPL - BGS GW Monitoring
Project State:	Iowa
Sampled By (Print):	
Sampled By (Sign):	
PO #:	Regulatory Program:

Pace Analytical® www.pacelabs.com

CHAIN OF CUSTODY

UPPER MIDWEST REGION
MN: 612-607-1700 WI: 920-469-2436

*Preservation Codes
A=None B=HCL C=H2SO4 D=HNO3 E=DI Water F=Methanol G=NaOH
H=Sodium Bisulfate Solution I=Sodium Thiosulfate J=Other

FILTERED? (YES/NO) Y/N
PRESERVATION (CODE)* Pick Letter
Analyses Requested

Quote #:	
Mail To Contact:	Tom Karwoski
Mail To Company:	SCS Engineers
Mail To Address:	2830 Dairy Drive Madison, WI 53718
Invoice To Contact:	Tom Karwoski
Invoice To Company:	SCS Engineers
Invoice To Address:	2830 Dairy Drive Madison, WI 53718
Invoice To Phone:	(608) 224-2830

Data Package Options (billable)
☐ EPA Level III
☐ EPA Level IV

MS/MSD
☐ On your sample (billable)
☐ NOT needed on your sample

Matrix Codes
A = Air, B = Biota, C = Charcoal, O = Oil, S = Soil, Sl = Sludge
W = Water, DW = Drinking Water, GW = Ground Water, SW = Surface Water, WW = Waste Water, WP = Wipe

PACE LAB #	CLIENT FIELD ID	COLLECTION DATE	COLLECTION TIME	MATRIX	CLIENT COMMENTS	LAB COMMENTS (Lab Use Only)	Profile #
	MW-301			GW			
	MW-302			GW			
	MW-303			GW			
	MW-304			GW			
	MW-305			GW			
	MW-306			GW			
	MW-307			GW			
	MW-308			GW			
	MW-309			GW			
	MW-310			GW			
	MW-311			GW			
	Field Blank			W			

Rush Turnaround Time Requested - Prelims
(Rush TAT subject to approval/surcharge)
Date Needed:

Transmit Prelim Rush Results by (complete what you want):

Email #1:	
Email #2:	
Telephone:	
Fax:	

Samples on HOLD are subject to special pricing and release of liability

Relinquished By:	Date/Time:	Received By:	Date/Time:

PACE Project No.

Receipt Temp = °C

Sample Receipt pH OK / Adjusted

Cooler Custody Seal
Present / Not Present
Intact / Not Intact

C019a(27Jun2006)

Version 6.0 06/14/06

ORIGINAL

APPENDIX C

Statistical Methodology for Groundwater Monitoring

APPENDIX C
Statistical Methodology for Groundwater Monitoring
Burlington Generating Station (BGS) – Interstate Power and Light Company (IPL)
October 2017

Groundwater monitoring data for the BGS CCR units will be evaluated in accordance with 40 CFR 257.93(f)(3), using a prediction interval procedure, in which an interval for each constituent is established from the distribution of the background data, and the level of each constituent in each compliance well is compared to the upper prediction limit.

Statistical evaluation will be performed using commercially available software (*Chemstat*, *Sanitas for Groundwater*© or similar) in general accordance with the USEPA's *Unified Guidance for Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* dated March 2009 (Unified Guidance) (USEPA, 2009) and generally accepted procedures.

The general procedures to be followed for statistical analysis of groundwater monitoring data are outlined below.

BACKGROUND MONITORING

A minimum of eight background samples will be collected prior to October 2017 for each Appendix III and Appendix IV constituent for each well in the monitoring system to develop the initial background data set for prediction limit analysis.

DETECTION MONITORING

The following data analysis will be performed for Appendix III parameters during detection monitoring to determinate whether a statistically significant increase (SSI) has occurred:

- Data Evaluation and Validation/Censoring
- Statistical Analysis using Prediction Limits

For the prediction limit calculation, the selection of interwell or intrawell testing will be based on the considerations outlined in Chapter 6 of the Unified Guidance, including natural background spatial variability, historical contamination associated with the sources other than the CCR unit(s), indications of contamination associated with the CCR unit(s), and background sample data set sizes.

For the initial detection monitoring event, interwell testing will be performed to compare compliance well concentrations to background well concentrations. If compliance well results do not significantly exceed background results and/or an alternative source demonstration indicates that higher concentrations in a compliance well are not associated with a release from the CCR unit(s), then intrawell testing may be implemented for future monitoring.

Data Evaluation and Validation/Censoring

In preparation for statistical analysis, data evaluation and validation/censoring steps will include:

- Averaging duplicate samples
- Validation and censoring
- Outlier analysis

Averaging Duplicate Samples

Field and laboratory quality assurance/quality control may involve the collection of one field duplicate per monitoring event. For data evaluation purposes, duplicates will be averaged with the original sample to form an independent data point before statistical analysis is performed.

Validation and Censoring

To filter analytical data that may not represent valid results, data from the monitoring events will be validated. Data flagged with a "J" qualifier indicates the quantitation of the parameter is less than the laboratory's LOQ but greater than the laboratory's LOD. Data flagged with a "B" qualifier indicated that the parameter was also detected in a trip blank, field blank, and/or method blank detection.

For compliance wells, non-detect data and data flagged with a "J" or "B" qualifier will not be subjected to statistical analysis for compliance purposes. Background data flagged with a "B" qualifier may not be included in the statistical analysis to preserve the power of the test to detect a potential release from the facility.

Outlier Analysis

Outlier analysis will be performed for background data to identify potential extreme values that may be due to sampling, laboratory, transportation, or transcription errors. Outlier analysis will be performed on background data for parameters for which statistical analysis will be performed. Background observations identified as outliers may not be included in the statistical analysis to preserve the power of the test to evaluate if the parameter detections are potentially due to the CCR unit.

Outlier analysis will include visual data review as well as statistical analysis as discussed in Chapter 12 of the Unified Guidance. The formal tests for outliers involve comparing the individual data points for each parameter within the same well against the remaining data from other sampling events. Dixon's test is recommended for small data sets (i.e., $n \leq 25$). Rosner's test is recommended for large data sets (i.e., $n > 25$). Probability plots and/or box plots may also be used for visual identification of outliers.

Statistical Analysis using Prediction Limits

Statistical analysis will be conducted for Appendix III parameters validated and quantified at a concentration equal to or above the laboratory's limit of quantitation (LOQ) in the compliance wells to evaluate if the parameter detections are potentially due to the CCR unit. The statistical analysis process involves:

- Evaluating Background Data
- Assessing Data Distribution
- Calculating Upper Prediction Limits (UPLs)
- Verification Retesting (as appropriate)

Evaluating Background Data

Background data for interwell analysis will be pooled from upgradient monitoring wells MW-310 and MW-311. The dates utilized for interwell analysis for the 1st semi-annual detection monitoring event, scheduled for October 2017, will include sampling events between April 1, 2016, and October 31, 2017. Background data for intrawell analysis will include compliance well results from sampling events between April 1, 2016, and August 31, 2017.

As described above, background data will be reviewed for outliers that should be removed prior to further statistical analysis.

The background data set will be updated for future monitoring events in accordance with the Unified Guidance.

Assessing Data Distribution

The assessment of the data distribution is critical for prediction limit calculations, as the selected formula is dependent on the data distribution. The Shapiro-Wilks test of normality is used to assess the distribution of background data for datasets with fewer than 50 data points. The Shapiro-Francia test of normality is used to assess the distribution of background data for datasets with 50 data points or more. Background data that are not determined to be normally distributed will also be evaluated to determine if the distribution can be transformed to a normal distribution by transforming the data (e.g., log or square root) and applying the same tests for normality. Data sets with greater than 50% non-detects will not be subjected to a data distribution evaluation, and the UPL will set using the non-parametric method.

Calculating Upper Prediction Limits

A prediction limit or interval is used to make a statement about one or more future "like" measurements. The Unified Guidance recommends using prediction limits with retesting as a means to lower facility-wide false positive rates while maintaining adequate statistical power to detect an SSI. Prior to constructing prediction limits with retesting following the Unified Guidance, a retesting plan must be specified based on the number of statistical evaluation periods per year, number of constituents, number of monitoring wells, and number of background results. The calculated UPL is then based on the retesting plan.

For initial detection monitoring at BGS, a 1-of-2 retesting plan will provide adequate statistical power to detect an SSI, while maintaining the annual target facility-wide false positive rate at no greater than 10% (cumulative throughout the year). The retesting plan can be modified in the future provided that the statistical power and site-wide false positive criteria are met. Any changes to the retesting plan should be documented before the sampling event begins.

The first number in the "_-of-_" retesting plan indicates the number of resamples that must not exceed the prediction limit in order to determine that an SSI has not occurred. The second number indicates the total number of samples required (i.e., the initial sample plus the resample). Therefore, in a 1-of-2 retesting approach, an SSI has occurred only if both the initial sample and the resample exceed the UPL.

The amount of background data that are below the limit of detection (LOD) plays an important role in selecting the appropriate statistical evaluation method and the resulting statistical calculation. If less than 15% of the background data observations are less than the reporting limit (non-detects), these will be replaced with one half of the reporting limit prior to running the analysis. If more than 15% but less than 50% of the background data are less than the reporting limit, the data's sample mean and sample standard deviation will be adjusted according to the method of Cohen or Aitchison. A non-parametric prediction limit will be calculated for data not transformed normal or containing greater than 50% non-detect results. As a general guideline, if 15% or fewer of the values are "not detected", the non-detect results will be replaced with the LOQ divided by two. If more than 15% but less than 50% of the values were reported as "not detected", the non-detect results will be adjusted using the Aitchison's Method or the Kaplan-Meier technique. The Aitchison's Method assumes that non-detects are actually free of the parameter being measured, so that the non-detect value can be regarded as a zero concentration. The Kaplan-Meier technique creates an estimate of the population mean and standard deviation adjusted for data censoring, based on the fitted distributional model. If 50% or greater of the data were reported as "not detected", a non-parametric statistical method will be utilized.

For any parameter with 100% non-detects in the background data, the Double Quantification rule will be used to evaluate the data for an SSI, as described in Chapter 6 of the Unified Guidance, which states:

> *A confirmed exceedance is registered if any well-constituent pair in the '100% non-detect' group exhibits quantified measurements (i.e., at or above the reporting limit [RL]) in two consecutive sample and resample events.*

When the background data are transformed to a normal distribution (e.g., data are lognormally distributed), the UPL is calculated using the transformed data and then the result is transformed back to its original scale.

When the background data or transformed data are not normally distributed or the percent of non-detects is greater than 50, a non-parametric UPL will be calculated.

Verification Retesting

For each semiannual sampling event, if an initial sample result exceeds the UPL, verification retesting may be performed. Retesting will generally be performed within 60 days of the initial sampling, to allow time to complete the sample analysis and data evaluation prior to the next semiannual event. As described above, in a 1-of-2 retesting approach, an SSI has occurred only if both the initial sample and the resample exceed the UPL.

IPL may choose not to retest one or more well/constituent pairs if the likelihood of the retest result being below the UPL appears low. If an initial sample result exceeds the UPL and the retest sample is not collected and analyzed in accordance with the retesting plan, then an SSI will be determined to have occurred.

ASSESSMENT MONITORING

If assessment monitoring is implemented, data analysis will be performed for Appendix IV parameters to determine whether an SSI over background has occurred for any required constituent. The assessment monitoring statistical evaluation process for comparison to background is the same as for detection monitoring.

Site-specific groundwater protection standard (GPS) values will be established for Appendix IV parameters in accordance with 40 CFR 257.95(h) as outlined below:

1. If an EPA maximum contaminant level (MCL) exists for a given parameter, and the UPL of the background data does not exceed the MCL, the GPS is set to the MCL.

2. If the UPL of the background data for a given parameter is greater than the EPA-MCL, the GPS is set to the background UPL.

3. If the MCL does not exist (not promulgated), the GPS is set to the background UPL.

Assessment monitoring results will be compared to the site-specific GPS values.

REVISIONS

This methodology for statistical evaluation of groundwater monitoring data may be revised as additional data are collected and/or in response to regulatory requirement or guidance changes. For example, the retesting approach may be modified as additional background results are obtained. Revisions will apply to future monitoring events performed after the change is made to the plan.

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Appendix C

Assessment of Corrective Measures

C1 Assessment of Corrective Measures (September 2019)

Assessment of Corrective Measures Existing Surface Impoundments

Burlington Generating Station
Burlington, Iowa

Prepared for:

Alliant Energy

SCS ENGINEERS

25218201.00 | September 12, 2019

2830 Dairy Drive
Madison, WI 53718-6751
608-224-2830

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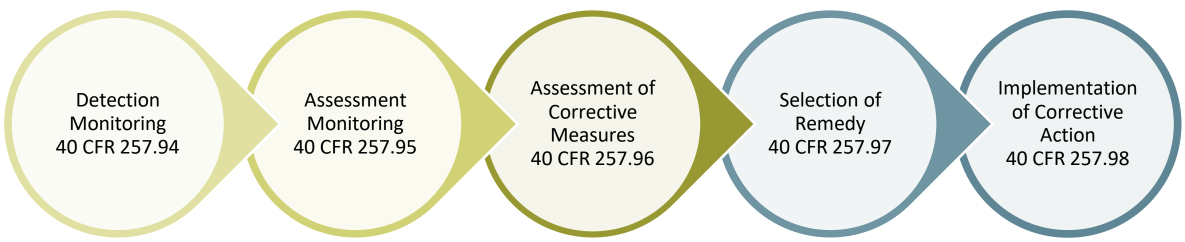
EXECUTIVE SUMMARY

Interstate Power and Light Company (IPL), an Alliant Energy company, operates four ash ponds at the Burlington Generating Station (BGS). The ponds are used to manage coal combustion residuals (CCR) and wastewater from the power plant, which burns coal and natural gas to generate electricity.

IPL samples and tests the groundwater in the area of the ash ponds to comply with U.S. Environmental Protection Agency (USEPA) standards for the Disposal of CCR from Electric Utilities, or the “CCR Rule” (Rule). Groundwater samples from some of the wells installed to monitor the ash ponds contained two metals, lithium and molybdenum, at levels higher than the Groundwater Protection Standards (GPS) defined in the Rule. These metals occur naturally, and both can be present in coal and CCR.

IPL has prepared this Assessment of Corrective Measures (ACM) Report in response to the groundwater sampling results at the BGS facility. The ACM process is one step in a series of steps defined in the Rule and shown below.



To prepare the ACM, IPL has worked to understand the following:

- Types of soil and rock deposits in the area of the BGS facility.
- Depth of groundwater.
- Direction that groundwater is moving.
- Potential sources of the lithium and molybdenum in groundwater.
- The area where lithium and molybdenum levels are higher than the USEPA standards.
- The people, plants, and animals that may be affected by levels of lithium and molybdenum in groundwater that are above the GPS.

IPL has installed new wells to help identify where lithium and molybdenum levels are higher than the USEPA standards. Because the time allowed by the Rule to prepare the ACM is limited, work to improve the understanding of the items listed above is still ongoing.

IPL has identified appropriate options, or Corrective Measures, to bring the levels of lithium and molybdenum in groundwater below USEPA standards. In addition to stopping the discharge of CCR and BGS wastewater to the ponds, these corrective measures include:

- Cap CCR in Place with Monitored Natural Attenuation (MNA)
- Consolidate CCR and Cap with MNA
- Excavate and Dispose CCR on Site with MNA
- Excavate and Dispose CCR in Off-site Landfill with MNA

IPL has also included a “No Action” alternative for comparison purposes only.

The ACM includes a preliminary evaluation of all five options using factors identified in the Rule.

Based on what is currently known, the groundwater impacts at BGS are limited, but are not completely understood. IPL will continue to work on understanding groundwater impacts at BGS, and will use this information to select one of the Corrective Measures identified above.

IPL will provide semiannual updates on its progress in evaluating Corrective Measures to address the groundwater impacts at BGS.

Before a remedy is selected, IPL will hold a public meeting with interested and affected parties to discuss the ACM.

For more information on Alliant Energy, view our 2019 Corporate Sustainability Report at http://www.alliantenergy.com/sustainability.

1.0 INTRODUCTION AND PURPOSE

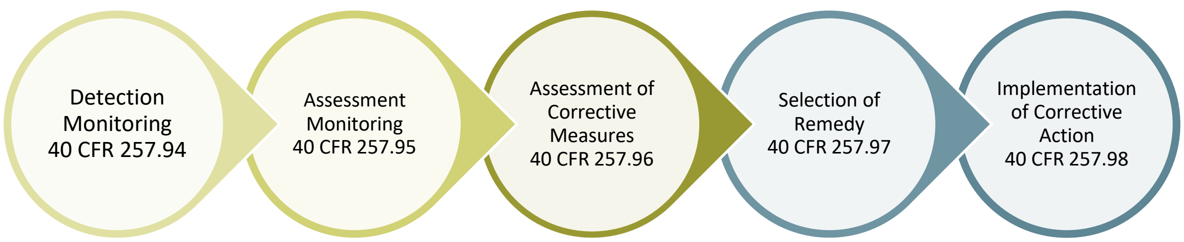
The Assessment of Corrective Measures (ACM) at the Interstate Power and Light Company (IPL) Burlington Generating Station (BGS) was prepared to comply with U.S. Environmental Protection Agency (USEPA) regulations regarding the Disposal of Coal Combustion Residuals (CCR) from Electric Utilities [40 CFR 257.50-107], or the "CCR Rule"(Rule). Specifically, the ACM was initiated and this report was prepared to fulfill the requirements of 40 CFR 257.96, including:

- Prevention of further releases
- Remediation of release
- Restoration of affected areas

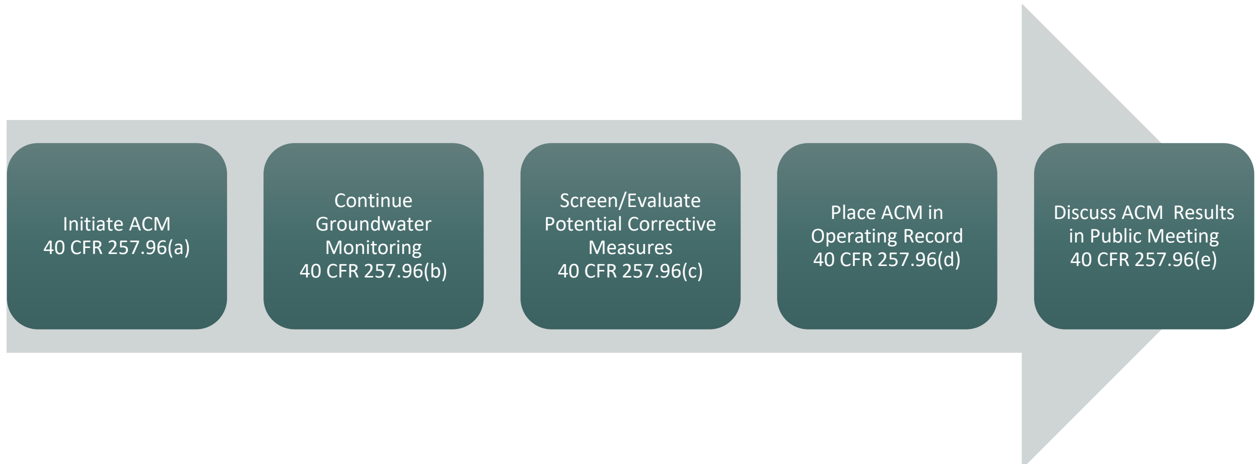
This ACM Report summarizes the remedial alternatives for addressing the Groundwater Protection Standard (GPS) exceedances observed in the October 2018 sampling event, and identified in the Notification of Groundwater Protection Standard Exceedance dated April 15, 2019.

1.1 ASSESSMENT OF CORRECTIVE MEASURES PROCESS

As discussed above, this ACM Report has been prepared in response to GPS exceedances observed in groundwater samples collected at the BGS facility. The ACM process is one step in a series of steps defined in the CCR Rule and depicted in the graphic below. To date, IPL has implemented a detection monitoring program per 40 CFR 257.94 and completed assessment monitoring at BGS per 40 CFR 257.95. An ACM is now required based on the groundwater monitoring results obtained through October 2018. With the ACM completed, IPL is required to select a corrective measure (remedy) according to 40 CFR 257.97. The remedy selection process must be completed as soon as feasible, and, once selected, IPL is required to start the corrective action process within 90 days.



The process for developing the ACM is defined in 40 CFR 257.96 and is shown in the graphic below. IPL is required to discuss the ACM results in a public meeting at least 30 days before selecting a remedy. To facilitate the selection of a remedy for the GPS exceedances at BGS, IPL continues to investigate and assess the nature and extent of the groundwater impacts. Information about the site, the groundwater monitoring completed, the groundwater impacts as they are currently understood, and the ongoing assessment activities are discussed in the sections that follow.



1.2 SITE INFORMATION AND MAP

BGS is located along the west bank of the Mississippi River, about 5 miles south of the city of Burlington, in Des Moines County, Iowa (**Figure 1**). The address of the plant is 4282 Sullivan Slough Road, Burlington, Iowa. In addition to the coal-fired generating station, the property also contains a coal stockpile, diesel-fueled combustion turbines, hydrated fly ash storage area, upper ash pond, lower pond, economizer ash pond, bottom ash pond, and ash seal pond.

The groundwater monitoring system at BGS is a multi-unit system. BGS includes four CCR Units:

- BGS Ash Seal Pond (existing CCR surface impoundment)
- BGS Main Ash Pond (existing CCR surface impoundment)
- BGS Economizer Ash Pond (existing CCR surface impoundment)
- BGS Upper Ash Pond (existing CCR surface impoundment)

These impoundments were included in the IPL, Notification of Intent to Close CCR Surface Impoundments, dated April 3, 2019. A map showing the CCR Units and all background (or upgradient) and downgradient monitoring wells with identification numbers for the CCR groundwater monitoring program is provided as **Figure 2**.

2.0 BACKGROUND

2.1 REGIONAL GEOLOGIC INFORMATION

The uppermost geologic formation beneath BGS that meets the definition of the "uppermost aquifer," as defined under 40 CFR 257.53, is the surficial alluvial aquifer. The alluvial aquifer comprises Mississippi River valley clay, silt, sand, and sand and gravel deposits. These deposits are present along the edges of the entire Mississippi River valley in southeastern Iowa. A map of the regional glacial geology in the area is included in **Appendix A.**

The alluvial aquifer is underlain by Devonian-Mississippian limestone bedrock, which is identified as an aquiclude on the regional bedrock geology map of the area included in **Appendix A.**

The regional groundwater flow direction is generally to the east toward the Mississippi River. A map of regional flow is included in **Appendix A.**

2.2 SITE GEOLOGIC INFORMATION

Monitoring wells MW-301 through MW-313 were installed to intersect the alluvial sands at the site. The unconsolidated material at these well locations is generally clay and silt to approximately 20 feet below ground surface (bgs), and these fine-grained sediments are underlain by sand or silty sand. The total boring depths are between 24 and 34 feet bgs. Bedrock was not encountered in any boring, indicating that the thickness of the alluvium at the site is at least 34 feet. The boring logs for MW-301 through MW-313 are included in **Appendix B**.

Shallow groundwater at the site generally flows to the east and southeast, toward the Mississippi River. The groundwater flow pattern for April 2019 is shown on **Figure 3**. The groundwater elevation data for the CCR monitoring wells are provided in **Table 1**.

A geologic cross section was prepared with background monitoring well MW-310 and downgradient monitoring wells MW-306 and MW-312. The cross section line runs through the lower southwest section of the BGS Upper Ash Pond, BGS Economizer Ash Pond, and the coal pile. The cross section location is provided on **Figure 4**, and the geologic cross section is provided on **Figure 5**. Unconsolidated geologic material and water table levels estimated using water levels measured at site monitoring wells are identified on the cross section.

2.3 CCR RULE MONITORING SYSTEM

The original groundwater monitoring system established in accordance with the CCR Rule consists of two upgradient (background) monitoring wells and nine downgradient monitoring wells. The background wells are MW-310 and MW-311. The nine initial downgradient wells are MW 301, MW-302, MW-303, MW304, MW-305, MW-306, MW-307, MW-308, and MW-309. These wells were installed between December 2015 and March 2016. Two additional downgradient monitoring wells, MW-312 and MW-313, were installed in May 2019 in accordance with the assessment monitoring requirements of 40 CFR 257.95(g)(1). The CCR Rule wells are installed in the upper portion of the alluvial aquifer. Well depths range from approximately 19 to 34 feet bgs.

3.0 NATURE AND EXTENT OF GROUNDWATER IMPACTS

3.1 POTENTIAL SOURCES

The potential sources of groundwater impacts are currently under evaluation. Based on the March 2018 History of Construction for BGS, prepared in accordance with §257.73(c) of the CCR Rule, potential sources of groundwater impacts from the monitored CCR units include the following:

CCR Unit	Potential Sources	Description	Quantity
Ash Seal Pond	CCR	Bottom ash, economizer ash, and precipitator ash	101,000 C.Y.
	Low volume waste water from generating plant	Legacy Operations	Regular flows ceased in 2009. May be used during maintenance operations.
	Stormwater	Annual precipitation	25.0 Acre-feet (AC-FT) (Watershed of 7.7 acres)

CCR Unit	Potential Sources	Description	Quantity
Main Ash Pond	CCR	Bottom ash, economizer ash, precipitator fly ash, and hydrated fly ash	445,000 C.Y.
	Low volume waste water from generating plant	Boiler seal water system, rinse water from previous chemical cleans, waste water from non-chemical metal cleaning (air heater wash and economizer wash), and boiler makeup/blowdown water	Average flow is approximately 0.63 million gallons per day (MGD).
	Stormwater	Annual precipitation	60.8 AC-FT. (Watershed of 18.7 acres)
Economizer Ash Pond	CCR	Economizer ash and precipitator fly ash	447,725 C.Y.
	Stormwater	Annual precipitation	35.8 AC-FT. (Watershed of 11-acres)
Upper Ash Pond	CCR	Bottom ash, economizer ash, and precipitator fly ash	114,150 C.Y.
	Low volume waste water flows from generating plant	Bottom ash sluicing activities, economizer ash sluicing activities, and process water flows from the generating plant	Average flow from April 2018 – April 2019 was 3.06 MGD.
	Stormwater	Annual Precipitation	43.2 AC-FT (Watershed of 13.3 acres)

Notes: Stormwater volume is calculated based on the watershed area for the pond and the annual average precipitation for Burlington, Iowa, of 39 inches/year. The average flow from the Main Ash Pond is based on 36 months of flow data for Outfall 006 over the period of 2006 through 2009. The calculation for average flow from the Upper Ash Pond excludes days when back waters affected flow measurements at Outfall 001.

3.2 GROUNDWATER ASSESSMENT

3.2.1 Groundwater Depth and Flow Direction

Depth to groundwater as measured in the site monitoring wells varies from 4 to 18 feet bgs due to topographic variations across the facility and seasonal variations in water levels. Groundwater flow at the site is generally to the east-southeast, and the groundwater flow direction and water levels fluctuate seasonally due to the proximity to the river.

3.2.2 Groundwater Protection Standard Exceedances Identified

The ACM process was triggered by the detection of lithium and molybdenum at statistically significant levels exceeding the Groundwater Protection Standards (GPSs) in samples from the following compliance wells:

- Lithium: MW-302, MW-307, MW-308

- Molybdenum: MW-302, MW-307, MW-308

This statistical evaluation of the assessment monitoring results was based on the first four sampling events for the Appendix IV assessment monitoring parameters, including complete sampling events in May, August, and October 2018, and a resampling event for selected wells in March 2019. The complete results for these sampling events are summarized in **Table 3**. Some additional compliance monitoring wells had individual results exceeding the GPSs for these parameters, but the exceedances were not determined to be at statistically significant levels. The evaluation of statistically significant levels exceeding the GPSs was summarized in an Alternative Source Demonstration (ASD) completed in April 2019. This ASD identified a reduced list of well-parameters exceeding the GPS and recommended that IPL initiate the ACM.

In the subsequent April 2019 sampling event, statistically significant levels exceeding the GPSs were identified for the following wells and parameters:

Assessment Monitoring Appendix IV Parameters	Location of GPS Exceedance(s)	Historic Range of Detections at Wells Exceeding GPS	Groundwater Protection Standards (GPS)
Lithium (µg/L)	MW-302, MW-303, MW-307, MW-308	34.3 – 82.4	40
Molybdenum (µg/L)	MW-302, MW-307, MW-308	47.4 - 159	100

µg/L = micrograms per liter
Note: Historic range includes results from assessment monitoring beginning in April 2018.

3.2.3 Expanding the Groundwater Monitoring Network

Monitoring wells MW-312 and MW-313 were installed in May 2019 downgradient of the CCR units and near the Mississippi River. Monitoring wells MW-312 and MW-313 were installed to expand the groundwater monitoring network at BGS beyond the edge of the CCR unit boundaries and to fulfill the requirements of 40 CFR 257.95(g)(1), which requires additional characterization to support a complete and accurate assessment of corrective measures. Groundwater samples were collected following installation of the two new monitoring wells.

The initial sampling results from MW-312 and MW-313, shown in **Table 3**, indicate that lithium exceeded the GPS in the sample from MW-313 and molybdenum exceeded the GPS in the samples from both wells. The statistical significance of the GPS exceedances for these wells and evaluation of alternative sources will be evaluated once additional sampling has been completed.

3.3 CONCEPTUAL SITE MODEL

The following conceptual site model describes the compounds and nature of constitutes above the GPS, discusses potential exposure pathways affecting human health and the environment, and presents a cursory review of their potential impacts. The conceptual site model for BGS has been prepared in general conformance with the Standard Guide for Developing Conceptual Site Models for Contaminated Sites (ASTM E1689-95). This conceptual site model is the basis for assessing the efficacy of likely corrective measures to address the source, release mechanisms, and exposure routes.

3.3.1 Nature of Constituents Above GPS

To describe the nature of the constituents in groundwater at BGS, we have reviewed a number of sources for information regarding lithium and molybdenum in groundwater, and how that groundwater may impact potential receptors through the exposure pathways discussed in Section 3.3.2.

Lithium

Lithium (Li) is an alkali metal that is naturally present in soil and water. Lithium is naturally present in coal and is present in CCR after the coal is combusted.

Lithium has numerous industrial and commercial uses, including as an additive aluminum production, a catalyst of chemical reactors, a component of fluxes and brazing alloys, a component of batteries, specialized glass and ceramics, and a sanitizing agent for swimming pools, hot tubs, and spas (USEPA, 2008). Primary food sources of lithium are grains and vegetables, and, in some areas, drinking water also contains lithium. Human intake varies depending on location and diet (Schrauzer, 2002).

Lithium Exposure

In November 2018, the United States Department of Health and Human Services (HHS) Agency for Toxic Substances and Disease Registry (ATSDR) provided a health consultation for an environmental case involving, among other constituents, lithium in groundwater (ATSDR, 2018). The report offered the following relevant to lithium in groundwater:

- Residences with sensitive subpopulations (individual undergoing lithium treatment, infants/children, pregnant women, those with significant renal or cardiovascular disease, etc.) should inform their physician of potential additional exposure to lithium through well water consumption.

- There is very limited toxicological literature on young children exposed to lithium. The potential for adverse health effects in sensitive subpopulations is uncertain because of the lack of relevant study data.

The concentrations of lithium detected to date in samples from the site monitoring wells range from below the detection limit to 82.4 μg/L. The GPS for lithium is 40 μg/L. The GPS for lithium is based on non-carcinogenic, child-based limits.

Molybdenum

Molybdenum (Mo) is a transitional metal that is naturally present in soil. Molybdenum is naturally present in coal and is present in CCR after the coal is combusted.

Molybdenum has industrial uses in metal alloys and chemical applications (London Metal Exchange [LME], 2007). Molybdenum is also an essential trace dietary element (Schwarz et al., 2013). Significant dietary sources of molybdenum include meats, green beans, eggs, sunflower seeds, wheat flour, lentils, cucumbers, and cereal grain (Emsley, 2001).

Acute toxicity has not been seen in humans, and the toxicity depends on the chemical state. Although human toxicity data are unavailable, animal studies have shown that chronic ingestion of more than 10 milligrams per day (mg/day) (10,000 micrograms per day [μg/day]) of molybdenum can cause diarrhea, growth retardation, infertility, low birth weight, and gout; it can also affect the lungs, kidneys, and liver (Coughlan, 1983) (Barceloux, Barcerloux, 1999).

Molybdenum Exposure
ATSDR prepared a Toxicological Profile for Molybdenum, draft for public comment dated April 2017. A copy of the draft profile is provided in Appendix C. The report offered the following with respect to molybdenum in surface water and groundwater:

- It has been reported that concentrations of molybdenum in surface waters are generally less than 1.0 µg/L, and drinking water and groundwaters contain about 1.0 µg/L. Near industrial sources, surface water molybdenum concentrations can reach 200 to 400 µg/L, and groundwater concentrations can reach 25,000 µg/L. Concentrations as high as 1,400 µg/L have been detected in drinking waters in areas impacted by mining and milling operations.

- USEPA has determined that exposure to drinking water containing 0.08 mg/L (80 µg/L) is not expected to cause effects that are harmful to children exposed for 1 or 10 days. Lifetime exposure to drinking water containing 0.04 mg/L (40 µg/L) is not likely to cause adverse health effects.

The concentrations of molybdenum detected to date in samples from the site monitoring wells range from below the detection limit to 290 µg/L. The GPS for molybdenum is 100 µg/L. The GPS for molybdenum is based on non-carcinogenic, child-based limits.

3.3.2 Potential Receptors and Pathways

As described in Section 3.3, ASTM E1689-95 provides a framework for identifying potential receptors (people or other organisms potentially affected by the groundwater impacts at BGS) and pathways (the ways groundwater impacts might reach receptors). In accordance with ASTM E1689-95, we have considered both potential human and ecological exposures to groundwater impacted by the constituents identified in Section 3.2.3:

Human Health
In general, human health exposure routes to contaminants in the environment include ingestion, inhalation, and dermal contact with the following environmental media:

- Groundwater
- Surface Water and Sediments
- Air
- Soil
- Biota/Food

If people might be exposed to the impacts described in Section 3.0 via one of the environmental media listed above, a potential exposure route exists and is evaluated further. For the groundwater impacts at BGS, the following potential exposure pathways have been identified with respect to human health:

- <u>Groundwater – Ingestion and Dermal Contact:</u> The potential for ingestion of, or dermal contact with, impacted groundwater from BGS exists if water supply wells are present in the area of impacted groundwater and are used as a potable water supply. Based on a review of the Iowa Department of Natural Resources (IDNR) GeoSam well database and information provided by BGS:

- No water supply wells have been identified downgradient or sidegradient in the vicinity of the CCR units.
- The on-site water supply well is not used as a source of potable water. Potable water at BGS is provided by the Rathbun Regional Water Association.

- Surface Water and Sediments – Ingestion and Dermal Contact: The potential for ingestion of or dermal contact with impacted surface water and sediments exists if impacted groundwater from the BGS facility has interacted with adjacent surface water and sediments, to the extent that the constituents identified in **Section 3.2.3** are present in these media at concentrations that represents a risk to human health.

- Biota/Food – Ingestion: The potential for ingestion of impacted food exists if impacted groundwater from the BGS facility has interacted with elements of the human food chain. Based on discussions with BGS facility staff, no hunting or farming occurs within the current area of known groundwater impacts. Elements of the food chain may also be exposed indirectly through groundwater-to-surface interactions, which are subject to additional assessment.

Based on the lack of groundwater exposure, only the surface water, sediment, and biota/food exposure pathways were retained for further consideration. However, the implementation of potential corrective measures may introduce secondary exposure pathways that are discussed in **Section 6.0** and will be evaluated further as a corrective measure is selected for BGS.

Ecological Health

In addition to human exposures to impacted groundwater, potential ecological exposures are also considered. If ecological receptors might be exposed to impacted groundwater, the potential exposure routes are evaluated further. Ecological receptors include living organisms, other than humans, the habitat supporting those organisms, or natural resources potentially adversely affected by CCR impacts. This includes:

- Transfer from an environmental media to animal and plant life. This can occur by bioaccumulation, bioconcentration, and biomagnification:
  - Bioaccumulation is the general term describing a process by which chemicals are taken up by a plant or animal either directly from exposure to impacted media (soil, sediment, water) or by eating food containing the chemical.

  - Bioconcentration is a process in which chemicals are absorbed by an animal or plant to levels higher than the surrounding environment; and

  - Biomagnification is a process in which chemical levels in plants or animals increase from transfer through the food web (e.g., predators have greater concentrations of a particular chemical than their prey)

- Benthic invertebrates within adjacent waters.

Based on the information presented in **Section 3.2.3** and the location of the Mississippi River adjacent to the current area of known groundwater impacts, both of these ecological exposure routes need to be evaluated further. Both potential ecological exposure pathways require groundwater-to-surface-water interactions for the exposure pathway to be complete. The groundwater-to-surface-water interactions at BGS are the subject of ongoing assessment.

The surface water/sediment, biota/food, and ecological exposure assessment is presently incomplete as the concentrations within surface water and sediment are presently unknown. The concentrations within groundwater are likely higher and not representative of the surface water subject to dermal contact and ingestion. Similarly, the concentrations within groundwater are likely higher than those interfacing the ecological receptors. Evaluation of constituent concentrations in sediment and surface water may be estimated through calculations and/or additional sampling.

4.0 POTENTIAL CORRECTIVE MEASURES

In this section, we identify potential corrective measures to meet the ACM goals identified in 40 CFR 257.96(a), which are to:

- Prevent further releases
- Remediate releases
- Restore affected areas to original conditions

The development of corrective measure alternatives is described further in the following sections. Corrective measure alternatives developed to address the groundwater impacts at BGS are described in **Section 5.0**. The alternatives selected are qualitatively evaluated in **Section 6.0**.

4.1 IDENTIFICATION OF CORRECTIVE MEASURES

As described in the USEPA Solid Waste Disposal Facility Criteria Technical Manual (USEPA, 1998), corrective measures generally include up to three components, including:

- Source Control
- Containment
- Restoration

Within each component, there are alternative measures that may be used to accomplish the component objectives. The measures from one or more components are then combined to form corrective measure alternatives (discussed in **Section 5.0**) intended to address the observed groundwater impacts. Potential corrective measures were identified based on site information available during development of the ACM for the purpose of meeting the goals described in **Section 4.0**.

Each component and associated corrective measures are further identified in subsequent paragraphs. The corrective measures are evaluated for feasibility and combined to create the corrective action alternatives identified in this section, and further evaluated in **Section 5.0**. We continue to evaluate site conditions and may identify additional corrective measures based on new information regarding the nature and extent of the impacts.

4.1.1 Source Control

The source control component of a corrective measure is intended to identify and locate the source of impacts and provide a mechanism to prevent further releases from the source. For the BGS site, the sources to be controlled are the CCR materials in the impoundments and the associated process water. Each of the source control measures below require closure of the impoundments, and for waste water to be re-directed from the CCR units to eliminate the flows that may mobilize constituents from the CCR and transport them to groundwater. We have identified the following potential source control measures:

- **Close and cap in place.** Close the CCR surface impoundments and cap the CCR in the four impoundments in place to reduce the infiltration of rain water into the impoundments, and prevent transport of CCR constituents from unsaturated CCR materials into the groundwater, and reduce the potential for CCR to interface with groundwater.

- **Consolidate and cap.** Consolidate CCR from the four CCR surface impoundments into one or two areas to reduce the potential source footprint, prevent transport of CCR constituents from unsaturated CCR materials into the groundwater, and minimize the potential for CCR to interface with groundwater.

- **Excavate and create on-site disposal area.** Excavate and place CCR in a newly lined landfill area on site to prevent further releases from the four potential source areas and isolate the CCR from potential groundwater interactions. Cap the new landfill with final cover to prevent the transport of CCR constituents from unsaturated CCR.

- **Excavate and dispose at a licensed off-site disposal area.** Remove all CCR from the site and haul to a licensed landfill to prevent further on site releases from the CCR areas.

Water movement through the CCR materials is the mechanism for CCR impacts to groundwater, including surface water that moves vertically through the CCR materials via infiltration of precipitation and surface water runoff.

Based on the available information for this site, all the source control measures have potential to prevent further releases caused by infiltration, thus are retained for incorporation into alternatives for further evaluation. However, we continue to investigate the source of groundwater impacts and, with new information, source control measures may be added or removed from consideration.

4.1.2 Containment

The objective of containment is to limit the spread of the impacts beyond the source. The need for containment depends on the nature and extent of impacts, exposure pathways, and risks to receptors. Containment may also be implemented in combination with restoration as described in Section 4.1.3.

Containment may be a recommended element of a corrective measure if needed to:

- Prevent off-site migration of groundwater impacts
- Cease completion of a confirmed exposure pathway (e.g., water supply well)

Containment may also be used in lieu of active restoration if an active approach is needed. However, containment with active treatment is not warranted when:

- Water in the affected aquifer is naturally unsuited for human consumption
- Contaminants are present in low concentration with low mobility
- Low potential for exposure pathways to be completed, and low risk associated with exposure
- Low transmissivity and low future user demand

The following containment measures have potential to limit the spread of continued or remaining groundwater impacts at this site, if necessary:

- **Gradient Control with Pumping.** Gradient control includes a measure to alter the groundwater velocity and direction to slow or isolate impacts. This can be accomplished with pumping wells and/or a trench/sump collection system. If groundwater pumping is considered for capturing an impacted groundwater plume, the impacted groundwater must be managed in conformance with all applicable federal and state requirements.

- **Gradient Control with Phytotechnology.** Gradient control with phytotechnology relies on the ability of vegetation to evapotranspire sources of surface water and groundwater. Water interception capacity by the aboveground canopy and subsequent evapotranspiration through the root system can limit vertical migration of water from the surface downward. The horizontal migration of groundwater can be controlled or contained using deep-rooted species, such as prairie plants and trees, to intercept, take up, and transpire the water. Trees classified as phreatophytes are deep-rooted, high-transpiring, water-loving organisms that send their roots into regions of high moisture and can survive in conditions of temporary saturation.

- **Chemical Stabilization.** Stabilization refers to processes that involve chemical reactions that reduce the leachability of lithium and molybdenum. Stabilization chemically immobilizes impacts or reduces their solubility through a chemical reaction. The desired results of stabilization methods include converting metals into a less soluble, mobile, or toxic form.

Based on the currently available information for this site, active containment (other than source control) is not currently required for this site and is not included in the proposed alternatives. We will continue to investigate the nature and extent of the groundwater impacts at BGS and may add containment measures as warranted by data.

4.1.3 Restoration

Restoration is the process through which groundwater quality is restored to meet GPSs. This can be accomplished by way of Monitored Natural Attention (MNA) or intensively addressed by groundwater treatment with or without extraction.

MNA can be a viable remedy or component of a remedial alternative for groundwater impacted with metals. MNA requires ongoing involvement and potentially intense characterization of the geochemical environmental to understand the attenuation processes involved, and to justify reliance on them and regular, long-term monitoring to ensure the attenuation processes are meeting remedial goals.

MNA is not a "do-nothing" alternative; rather it is an effective knowledge-based remedy where a thorough engineering analysis provides the basis for understanding, monitoring, predicting, and documenting natural processes. To properly employ this remedy, there needs to be a strong scientific basis supported by appropriate research and site-specific monitoring implemented in accordance with quality controls. The compelling evidence needed to support proper evaluation of the remedy requires that the processes that lower metal concentrations in groundwater be well understood.

If active treatment is implemented, water may be treated in-situ, on-site, or off-site. The need for active treatment depends on the nature and extent of impacts, exposure pathways, and risks to receptors. If there are no receptors, or when active treatment is not required for the reasons discussed in Section 4.1.2, then MNA is an appropriate option. If existing or future impacts require a more rapid restoration of groundwater quality, then active restoration may be needed.

Treated groundwater may be re-injected, sent to a local publicly owned treatment works (POTW), or discharged to a local body of surface water, depending on local, state, and federal requirements. Typical on-site treatment practices for metals include coagulation and precipitation, ion exchange, or reverse osmosis. Off-site wastewater treatment may include sending the impacted groundwater that is extracted to a local POTW or to a facility designed to treat the contaminants of concern.

The removal rate of groundwater constituents such as lithium and molybdenum will depend on the rate of groundwater extraction, the cation exchange capacity of the soil, and partition coefficients of the constituents sorbed to the soil. As the concentration of metals in groundwater is reduced, the rate at which constituents become partitioned from the soil to the aqueous phase may also be reduced. The amount of flushing of the aquifer material required to remove the metals and reduce their concentration in groundwater below the GPS will generally determine the time frame required for restoration. This time frame is site-specific.

In-situ methods may be appropriate, particularly where pump and treat technologies may present adverse effects. In-situ methods may include biological restoration requiring pH control, addition of specific micro-organisms, and/or addition of nutrients and substrate to augment and encourage degradation by indigenous microbial populations. Bioremediation requires laboratory treatability studies and pilot field studies to determine the feasibility and the reliability of full-scale treatment.

Based on current information, MNA is retained for incorporation into alternatives for further evaluation. Other restoration measures are not currently required for this site, but may be added following continued investigation of the nature and extent of groundwater impacts.

5.0 CORRECTIVE MEASURE ALTERNATIVES

We have preliminarily identified the following corrective measure alternatives for the groundwater impacts at BGS:

- Alternative 1 – No Action
- Alternative 2 – Close and Cap in Place with MNA
- Alternative 3 – Consolidate and Cap with MNA
- Alternative 4 – Excavate and Dispose on Site with MNA
- Alternative 5 – Excavate and Dispose in Off-site Landfill with MNA

These alternatives were developed by selecting components from the reasonable and appropriate corrective measures components discussed above. With the exception of the No Action alternative, each of the corrective measure alternatives meet the requirements in 40 CFR 257.97(b)(1) through (5) based on the information available at the current time. We may identify additional alternatives based on the continued evaluation of site conditions.

5.1 ALTERNATIVE 1 – NO ACTION

IPL is committed to implementing corrective measures as required under the Rule and the No-Action alternative is only included as a baseline condition and a point of comparison for the other alternatives. The consideration of this alternative assumes the monitoring of groundwater continues under this action.

5.2 ALTERNATIVE 2 – CLOSE AND CAP IN PLACE WITH MNA

Alternative 2 includes closing the impoundments (no further discharge), covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d). This measure is consistent with landfill cover systems to prevent infiltration of surface water into the CCR as described in **Section 4.1.1**. The capped areas will be subject to enhanced groundwater monitoring via MNA.

This alternative eliminates CCR sluicing/plant process water discharges and, with the installation of a cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. Further leaching of metals and migration within groundwater will be reduced and may be eliminated over time. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

5.3 ALTERNATIVE 3 – CONSOLIDATE ON-SITE AND CAP WITH MNA

Alternative 3 includes closing the impoundments (no further discharge), relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d). This measure is consistent with landfill cover systems to prevent infiltration of surface water into the CCR as described in **Section 4.1.1**. The consolidated and capped areas will be subject to enhanced groundwater monitoring via MNA.

This alternative eliminates CCR sluicing/plant process water discharges and, with the consolidation of the CCR footprint and the installation of a cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. Further leaching of metals and migration within groundwater will be reduced and may be eliminated over time. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

5.4 ALTERNATIVE 4 – EXCAVATE AND DISPOSE ON-SITE WITH MNA

Alternative 4 includes closing the impoundments (no further discharge), excavation of CCR from the source area, and creation of a new on-site disposal area with a liner and cap system. This alternative will serve to contain the CCR at the site and allow for the collection and management of liquids generated from the disposal area. Further releases from the current source will be prevented by the use of engineering controls constructed/installed to meet the design criteria for new CCR landfills required under 40 CFR 257.70.

This alternative eliminates CCR sluicing/plant process water discharges and, with the consolidation of the CCR footprint and the installation of a new on-site disposal area liner and cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

5.5 ALTERNATIVE 5 – EXCAVATE AND DISPOSE IN OFF-SITE LANDFILL WITH MNA

Alternative 5 includes closing the impoundments (no further discharge), excavation of all CCR, and transport to an approved off-site landfill. Further on site releases from the CCR sources will be prevented by relocating the source material to another site, which eliminates the potential for ongoing leaching of constituents into groundwater at BGS.

This alternative eliminates CCR sluicing/plant process water discharges and, with the removal of CCR from the site, will eliminate infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

6.0 EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

As required by 40 CFR 257.96(c), the following sections provide an evaluation of the effectiveness of corrective measure alternatives in meeting the requirements and objectives outlined in 40 CFR 257.97. The evaluation addresses the requirements and objectives identified in 40 CFR 257.96(c)(1) through (3), which include:

- The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to residual contamination;
- The time required to begin and complete the remedy; and
- The institutional requirements, such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy.

In addition to the discussion of the items listed above, **Table 4** provides a summary of the initial evaluation of the alternatives including each of the criteria listed in 40 CFR 257.97.

6.1 ALTERNATIVE 1 – NO ACTION

As described in **Section 5.1**, the No Action alternative is only included as a baseline condition and a point of comparison for the other alternatives. This alternative does not satisfy all five criteria in 40 CFR 257.97(b)(1) through (5), so it is not an acceptable corrective measure under the CCR Rule. For comparison only, Alternative 1 is evaluated with regard to the criteria in 40 FR 257.96(c) below:

- **Performance, Reliability, Implementation, and Impacts.**
  - Performance – The ability to attain the GPS for lithium and molybdenum without any additional action is unlikely.

- Reliability – Alternative 1 does not provide any reduction in existing risk.
- Implementation – Nothing is required to implement Alternative 1.
- Impacts – No additional safety or cross-media impacts are expected with Alternative 1. This alternative does not control current suspected routes of exposure to residual contamination.

- **Timing.** No time is required to begin. However, the time required to attain the GPS for lithium and molybdenum under Alternative 1 is unknown.

- **Institutional Requirements.** No institutional requirements beyond maintaining current regulatory approvals exist for Alternative 1.

6.2 ALTERNATIVE 2 – CLOSE AND CAP IN PLACE WITH MNA

As described in **Section 5.2**, Alternative 2 includes closing the impoundments, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d).

- **Performance, Reliability, Implementation, and Impacts.**
  - Performance – Ceasing wastewater discharges and closing the impoundments by capping is expected to address infiltration, which is a key contributor to groundwater impacts. MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 2 is capable of and expected to attain the GPS for lithium and molybdenum.

  - Reliability – The expected reliability of capping is good. Capping is a common practice and standard remedial method for closure in place in remediation and solid waste management. There is significant industry experience with the design and construction of this method.

  - Implementation – The complexity of constructing the cap is low. Dewatering will be required to the extent a suitable subgrade is established for cap construction, which can likely be achieved through standard dewatering methods. The cap construction may put a high demand on the local supply of suitable cap materials. The local availability of cap materials will be evaluated further during remedy selection. The equipment and personnel required to implement Alternative 2 are not specialized and are generally readily available.

  - Impacts – Safety impacts associated with the implementation of Alternative 2 are not significantly different than other heavy civil construction projects. Cross-media impacts are expected to be limited due to the small volume of CCR expected to be relocated on site, the short duration of cap construction, the effectiveness of standard engineering controls during construction (e.g., dust control), and the lack of off-site transportation of CCR. The potential for exposure to residual contamination is low since CCR will be capped.

- **Timing.** Closure of the impoundments can be completed within 1-2 years following cessation of ash placement in the impoundments. Coal will no longer be used as a fuel at BGS after December 31, 2021, and the closure of the impoundments is expected to be completed by the end of 2023. The time required to attain the GPS for lithium and molybdenum will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. Alternative 2 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 2:
  - IDNR Closure Permit
  - Federal, state, and local floodplain permits
  - State and local erosion control/construction stormwater management permits

  Federal and state wetland permitting may also be required.

6.3 ALTERNATIVE 3 – CONSOLIDATE ON-SITE AND CAP WITH MNA

As described in **Section 5.3**, Alternative 3 includes closing the impoundments, relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d).

- **Performance, Reliability, Implementation, and Impacts.**
  - Performance – Ceasing wastewater discharges and closing the impoundments by capping is expected to address infiltration, which is a key contributor to groundwater impacts. The consolidation of CCR into a smaller footprint may enhance the performance of the cap by further reducing the area exposed to limited post-construction infiltration through the cap. MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 3 is capable of and expected to attain the GPS for lithium and molybdenum.

  - Reliability – The expected reliability of capping is good. Capping is a common practice and standard remedial method for closure in place in remediation and solid waste management. There is significant industry experience with the design and construction of this method. A consolidated cap footprint may enhance reliability by reducing the scale of post-closure maintenance.

  - Implementation – The complexity of constructing the cap is low. The logistics of moving CCR around the site to consolidate the closure footprint increases the complexity of the alternative. CCR dewatering will be required to the extent required to excavate and relocate CCR within the CCR impoundments and provide a suitable subgrade for cap construction. Some conditioning (e.g., drying) of relocated CCR is expected during on-site re-disposal. Alternative 3 can likely be achieved through standard dewatering and conditioning methods. Although the cap footprint will be minimized, cap construction may put a high demand on the local supply of suitable cap materials. The local availability of cap materials will be evaluated further during remedy selection. The equipment and personnel required to implement Alternative 3 are not specialized and are generally readily available.

  - Impacts – Safety impacts associated with the implementation of Alternative 3 are not significantly different than other heavy civil construction projects. The level of disturbance required to consolidate CCR before capping may represent some increase in safety risk due to site conditions and on-site construction traffic. Cross-media impacts are expected to be limited due to the small volume of CCR expected to be relocated on site, the short duration of cap construction, the effectiveness of standard engineering controls during construction (e.g., dust control), and the lack of off-site transportation of CCR. The potential for exposure to residual contamination is low since CCR will be capped and the footprint of the cap minimized.

- **Timing.** Closure of the impoundments can be completed within 1-2 years following cessation of ash placement in the impoundments. Coal will no longer be used as a fuel at BGS after December 31, 2021, and the closure of the impoundments is expected to be completed by the end of 2023. The time required to attain the GPS for lithium and molybdenum will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The consolidation of CCR into a smaller cap area may decrease the time to reach GPS. Alternative 3 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 3:
  - IDNR Closure Permit
  - Federal, state, and local floodplain permits
  - State and local erosion control/construction stormwater management permits
  - Federal and state wetland permitting may also be required.

6.4 ALTERNATIVE 4 – EXCAVATE AND DISPOSE ON-SITE WITH MNA

As described in **Section 5.4**, Alternative 4 includes closing the impoundments, excavation of CCR from the source area, and creation of a new on-site disposal that meets the design criteria for new CCR landfills required under 40 CFR 257.70

- **Performance, Reliability, Implementation, and Impacts.**
  - Performance – Ceasing wastewater discharges and closing the impoundments by removing and re-disposing CCR in a new lined/capped disposal area is expected to address infiltration, which is a key contributor to groundwater impacts. The consolidation of CCR into a smaller footprint may enhance the performance of the cap by further reducing the area exposed to limited post-construction infiltration through the cap. The separation from groundwater and other location criteria for the new on-site disposal facility may enhance the performance of this alternative. MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 4 is capable of and expected to attain the GPS for lithium and molybdenum.

  - Reliability – The expected reliability of on-site re-disposal with a composite liner and cap is good. Disposal facilities that meet the requirements in 40 CFR 257.70 or other similar requirements have been used for solid waste disposal including municipal and industrial waste for numerous years. There is significant industry experience with the design and construction of similar disposal facilities. The composite liner and cover combined with a consolidated disposal footprint may enhance reliability by reducing infiltration and the scale of post-closure maintenance. At the same time, post-closure maintenance is likely more complex due to maintenance of a leachate collection system and geosynthetic repairs requiring specialized personnel, material, and equipment.

- Implementation – The complexity of constructing the new liner and cap is moderate due to the composite design. The limited area available at the facility for developing an on-site disposal facility makes this alternative logistically complex. Significant volumes of CCR will be excavated and stored on site while the disposal facility is constructed. Significant dewatering will be required to excavate and relocate CCR to a temporary storage area. Conditioning (e.g., drying) of relocated CCR is expected to facilitate temporary storage and on-site re-disposal. Alternative 4 can likely be achieved through standard dewatering and conditioning methods, but may be impacted by the space available for these activities. Although the post-closure CCR footprint will be minimized, composite liner and cap construction may put a high demand on the local supply of suitable cap materials. The local availability of liner and cap materials will be evaluated further during remedy selection. The equipment and personnel required to implement Alternative 4 are not specialized and are generally readily available with the exception of the resources needed to install the geosynthetic portions of the composite liner and cover, which are not locally available.

- Impacts – Safety impacts associated with the implementation of Alternative 4 are not significantly different than other heavy civil construction projects. However, the level of disturbance required to excavate, store, and re-dispose CCR on site and the traffic required to import composite liner and cap material are not typical and likely represent an increase in safety risk due to site conditions, on-site construction traffic, and incoming/outgoing off-site construction traffic. A risk of cross-media impacts is possible due to the large volume of CCR to be excavated, stored, and relocated on site. The potential for exposure to residual contamination is low since CCR will be capped and the footprint of the cap minimized.

- **Timing.** Closure of the impoundments can be completed within 1-2 years following cessation of ash placement in the impoundments. Coal will no longer be used as a fuel at BGS after December 31, 2021, and the closure of the impoundments is expected to be completed by the end of 2023. However, the time required to permit and develop the on-site disposal facility may extend this schedule. The time required to attain the GPS for lithium and molybdenum will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The consolidation of CCR into a new on-site disposal facility with a composite liner and cap may decrease the time to reach GPS. Alternative 4 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 4:
  - IDNR Closure Permit
  - IDNR Disposal Facility (Landfill) Permit
  - Federal, state, and local floodplain permits
  - State and local erosion control/construction stormwater management permits
  - Federal and state wetland permitting

6.5 ALTERNATIVE 5 – EXCAVATE AND DISPOSE IN OFF-SITE LANDFILL WITH MNA

As described in **Section 5.5**, Alternative 5 includes closing the impoundments, excavation of CCR from the source area, and transporting the CCR off site for disposal.

- **Performance, Reliability, Implementation, and Impacts.**
  - Performance – Ceasing wastewater discharges and closing the impoundments by removing and re-disposing CCR off site will eliminate the source material exposed to infiltration, which is a key contributor to groundwater impacts. The off-site disposal of CCR prevents further releases at BGS, but introduces the possibility of releases at the receiving facility. MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 5 is capable of and expected to attain the GPS for lithium and molybdenum.

  - Reliability – The expected reliability of excavation and off-site disposal is good. Off-site disposal facilities are required to meet the requirements in 40 CFR 257.70 or other similar requirements, which have been used for solid waste disposal including municipal and industrial waste for numerous years. There is significant industry experience with the design and construction of these disposal facilities.

  - Implementation – The complexity of excavating CCR for off-site disposal is low. The scale of CCR excavation (expected to exceed 1 million cy), off-site transportation, and the permitting/development of off-site disposal facility airspace makes this alternative logistically complex. Significant dewatering will be required to excavate CCR. Conditioning (e.g., drying) of excavated CCR is expected to facilitate off-site transportation and re-disposal. Alternative 5 can likely be achieved through standard dewatering and conditioning methods, but may be impacted by the space available for these activities. Although the source area at BGS is eliminated, the development of off-site disposal airspace will put a high demand on the receiving disposal facility, which may not have the current physical or logistical capacity to receive large volumes of CCR in a short period of time. The equipment and personnel required to implement on-site and off-site aspects of Alternative 5 are not specialized and are generally readily available with the exception of the resources needed to install the geosynthetic portions of the off-site composite liner and cover, which are not locally available.

  - Impacts – Safety impacts associated with the implementation of Alternative 5 are not significantly different than other heavy civil construction projects. However, the level of disturbance required to excavate, transport, and re-dispose CCR and the traffic required to import composite liner and cap material at the receiving disposal facility are not typical and likely represent an increase in safety risk due to large volumes of incoming/outgoing off-site construction traffic at both sites. A risk of cross-media impacts is possible due to the large volume of CCR to be excavated and transported from the site. The potential for exposure to residual contamination on site is very low since CCR will be removed; however, the off-site potential for exposure to CCR is increased due to the relocation of the source material.

- **Timing.** Closure of the impoundments can be completed within 1-2 years following cessation of ash placement in the impoundments. Coal will no longer be used as a fuel at

BGS after December 31, 2021, and the closure of the impoundments is expected to be completed by the end of 2023. However, the time required to secure the off-site disposal airspace required to complete this alternative, including potential procurement, permitting, and construction, may extend this schedule significantly. The time required to attain the GPS for lithium and molybdenum will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The removal of CCR from BGS may decrease the time to reach GPS. Alternative 5 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 5:
  - IDNR Closure Permit
  - Approval of off-site disposal facility owner or landfill permit for new off-site facility
  - Federal, state, and local floodplain permits
  - State and local erosion control/construction stormwater management permits
  - Federal and state wetland permitting
  - Transportation agreements and permits (local roads and railroads)

  State solid waste comprehensive planning approvals may also be required.

7.0 SUMMARY OF ASSESSMENT

Each of the identified corrective measure alternatives exhibit favorable and unfavorable outcomes with respect to the assessment factors that must be evaluated in accordance with 40 CFR 257.97(c). At the present time, limited impacts have been identified as described in **Section 3.0**. The nature and extent of those impacts are the subject of ongoing assessment and IPL continues to assess remedies to meet the requirements and objectives described in 40 CFR 257.97.

8.0 REFERENCES

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Tables

Table 1. Water Level Summary
Burlington Generating Station / SCS Engineers Project #25218201.00

Raw Data	Depth to Water in feet below top of well casing												
	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306	MW-307	MW-308	MW-309	MW-310	MW-311	MW-312	MW-313
Measurement Date													
April 20, 2016	15.75	13.78	11.84	12.64	11.32	15.18	14.58	15.27	14.33	6.56	8.60	NM	NM
June 6 & 7, 2016	17.31	14.48	12.34	13.14	11.80	15.49	15.21	15.77	15.03	7.86	10.52	NM	NM
August 16 & 17, 2016	16.57	14.34	12.29	13.05	11.82	15.39	15.05	15.64	14.72	7.15	9.40	NM	NM
October 3, 2016	10.90	8.15	6.03	6.85	5.57	9.25	9.15	9.58	8.85	4.41	4.98	NM	NM
January 9 & 10, 2017	13.00	10.19	8.04	8.80	7.54	11.25	11.15	11.55	10.85	6.21	7.16	NM	NM
April 3 & 4, 2017	15.30	12.85	10.79	11.55	10.25	13.85	13.82	14.13	13.3	6.47	8.31	NM	NM
June 12 & 13, 2017	15.17	12.85	10.80	11.52	10.50	14.05	13.79	14.30	13.51	7.05	8.77	NM	NM
August 15 & 16, 2017	18.42	16.30	14.30	15.19	13.35	17.10	16.80	17.40	16.49	8.10	11.20	NM	NM
October 16, 2017	16.25	13.49	11.37	12.10	10.80	14.20	14.41	14.74	13.75	6.50	8.88	NM	NM
May 8 & 9, 2018	12.87	9.88	7.80	8.57	7.22	10.92	10.90	11.58	10.88	6.20	7.24	NM	NM
August 13 & 14, 2018	18.19	15.82	13.82	14.61	12.99	16.78	16.50	16.98	16.20	8.30	11.26	NM	NM
October 9 &10, 2018	10.37	7.61	4.82	5.60	4.31	7.97	7.88	8.22	7.49	2.99	3.83	NM	NM
March 11, 2019	15.00	12.86	10.86	11.62	NM	13.71	13.47	14.07	NM	NM	NM	NM	NM
April 3, 2019	10.23	7.48	5.38	6.15	4.92	8.52	8.33	8.81	8.02	3.37	4.12	NM	NM
June 6, 2019	7.68	4.67	2.60	3.38	TOC	5.73	5.58	6.05	5.34	0.51	1.25	5.35	4.77

	Groundwater Elevation in feet above mean sea level (amsl)												
Well Number	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306	MW-307	MW-308	MW-309	MW-310	MW-311	MW-312	MW-313
Top of Casing Elevation (feet amsl)	538.38	535.69	533.60	534.42	533.28	536.92	536.96	537.20	536.42	531.99	532.32	536.43	535.82
Screen Length (ft)													
Total Depth (ft from top of casing)	31.90	29.95	28.59	25.27	29.43	34.41	28.64	30.31	27.31	18.76	22.63	27.70	32.97
Top of Well Screen Elevation (ft)	511.48	510.74	510.01	514.15	508.85	507.51	513.32	511.89	514.11	518.23	514.69	513.80	507.85
Measurement Date													
April 20, 2016	522.63	521.91	521.76	521.78	521.96	521.74	522.38	521.93	522.09	525.43	523.72	NM	NM
June 6 & 7, 2016	521.07	521.21	521.26	521.28	521.48	521.43	521.75	521.43	521.39	524.13	521.80	NM	NM
August 16 & 17, 2016	521.81	521.35	521.31	521.37	521.46	521.53	521.91	521.56	521.70	524.84	522.92	NM	NM
October 3, 2016	527.48	527.54	527.57	527.57	527.71	527.67	527.81	527.62	527.57	527.58	527.34	NM	NM
January 9 & 10, 2017	525.38	525.50	525.56	525.62	525.74	525.67	525.81	525.65	525.57	525.78	525.16	NM	NM
April 3 & 4, 2017	523.08	522.84	522.81	522.87	523.03	523.07	523.14	523.07	523.10	525.52	524.01	NM	NM
June 12 & 13, 2017	523.21	522.84	522.80	522.90	522.78	522.87	523.17	522.90	522.91	524.94	523.55	NM	NM
August 15 & 16, 2017	519.96	519.39	519.30	519.23	519.93	519.82	520.16	519.80	519.93	523.89	521.12	NM	NM
October 16, 2017	522.13	522.20	522.23	522.32	522.48	522.72	522.55	522.46	522.67	525.49	523.44	NM	NM
May 8 & 9, 2018	525.51	525.81	525.80	525.85	526.06	526.00	526.06	525.62	525.54	525.79	525.08	NM	NM
August 13 & 14, 2018	520.19	519.87	519.78	519.81	520.29	520.14	520.46	520.22	520.22	523.69	521.06	NM	NM
October 9 &10, 2018	528.01	528.08	528.78	528.82	528.97	528.95	529.08	528.98	528.93	529.00	528.49	NM	NM
March 11, 2019	523.38	522.83	522.74	522.80	NM	523.21	523.49	523.13	NM	NM	NM	NM	NM
April 3, 2019	528.15	528.21	528.22	528.27	528.36	528.40	528.63	528.39	528.40	528.62	528.20	NM	NM
June 6, 2019	530.70	531.02	531.00	531.04	TOC	531.19	531.38	531.15	531.08	531.48	531.07	531.08	531.05
Bottom of Well Elevation (ft)	506.48	505.74	505.01	509.15	503.85	502.51	508.32	506.89	509.11	513.23	509.69	508.73	502.85

Notes:
NM = not measured
TOC = top of casing

Created by: KAK Date: 6/15/2016
Last revision by: JR Date: 7/12/2019
Checked by: JSN Date: 7/15/2019

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Table 2. CCR Rule Groundwater Samples Summary
Burlington Generating Station / SCS Engineers Project #25218201.00

Sample Dates	Downgradient Wells											Background Wells	
	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306	MW-307	MW-308	MW-309	MW-312	MW-313	MW-310	MW-311
4/20-21/2016	B	B	B	B	B	B	B	B	B	--	--	B	B
6/6-7/2016	B	B	B	B	B	B	B	B	B	--	--	B	B
8/16-17/2016	B	B	B	B	B	B	B	B	B	--	--	B	B
10/3/2016	B	B	B	B	B	B	B	B	B	--	--	B	B
1/9-10/2017	B	B	B	B	B	B	B	B	B	--	--	B	B
4/3-4/2017	B	B	B	B	B	B	B	B	B	--	--	B	B
6/12-13/2017	B	B	B	B	B	B	B	B	B	--	--	B	B
8/15-16/2017	B	B	B	B	B	B	B	B	B	--	--	B	B
10/16-17/2017	D	D	D	D	D	D	D	D	D	--	--	D	D
5/8-9/2018	A	A	A	A	A	A	A	A	A	--	--	A	A
8/13-14/2018	A	A	A	A	A	A	A	A	A	--	--	A	A
10/9-10/2018	A	A	A	A	A	A	A	A	A	--	--	A	A
3/12-13/2019	R	R	R	R	--	R	R	R	--	--	--	--	--
4/3-4/2019	A	A	A	A	A	A	A	A	A	--	--	A	A
6/6/2019	--	--	--	--	--	--	--	--	--	A	A	--	--

Abbreviations:
A = Required by Assessment Monitoring Program
B = Background Sample
-- = Not applicable
D = Required by Detection Monitoring Program
R = Resample Event

Created by: NDK Date: 6/18/2019
Last revision by: MDB Date: 6/20/2019
Checked by: NDK Date: 6/20/2019

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Table 3. Groundwater Analytical Results Summary - CCR Program - Assessment Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25218201.00

Background Wells

Parameter Name	UPL Method	UPL	GPS	MW-310 5/9/2018	MW-310 8/14/2018	MW-310 10/10/2018	MW-310 4/4/2019	MW-311 10/16/2017	MW-311 5/9/2018	MW-311 8/14/2018	MW-311 10/10/2018	MW-311 4/4/2019
Appendix III												
Boron, ug/L	NP	2,950		217	256	268	560	2,810	2,200	2,580	2,820	1,800
Calcium, mg/L	P	210		104	102	107	120	145	173	156	130	200
Chloride, mg/L	P	209		24.4	33.8	67.1	88	50.9	79.9	69.9	54	110
Fluoride, mg/L	P	0.427		0.33	0.39	0.4	0.55	0.36	0.31	0.36	0.35	0.41 J
Field pH, Std. Units	P	8.17		7.46	7.44	7.20	7.84	8.27	7.26	7.33	7.49	7.64
Sulfate, mg/L	P	457		28.8	27.2	37.9	21	119	176	144	127	230
Total Dissolved Solids, mg/L	P	1,113		462	472	512	600	615	864	777	678	980
Appendix IV		**UPL**	**GPS**									
Antimony, ug/L	P*	0.17	6	<0.026	<0.15	<0.078	<0.53	NA	<0.026	<0.15	<0.078	<0.53
Arsenic, ug/L**	P	114.9	114.9	57.8	56.2	62.1	65	NA	14.0	15.7	15.2	19
Barium, ug/L	P	1,147	2,000	403	398	450	560	NA	256	239	214	280
Beryllium, ug/L	NP*	0.036	4	<0.012	<0.12	<0.089	<0.27	NA	<0.023 D3	<0.12	<0.089	<0.27
Cadmium, ug/L	NP*	0.025	5	<0.018	<0.070	<0.033	<0.077	NA	<0.018	<0.070	<0.033	<0.077
Chromium, ug/L	P*	0.090	100	0.16 J,B	<0.19	0.082 J	<0.98	NA	0.20 J,B	0.22 J	0.78 J	<0.98
Cobalt, ug/L	P	3.87	6	1.2	1.4	1.4	1.9	NA	0.30 J	0.37 J	0.57 J	0.45 J
Fluoride, mg/L	P	0.427	4	0.33	0.39	0.4	0.55	NA	0.31	0.36	0.35	0.41 J
Lead, ug/L	NP*	0.64	15	0.044 J	<0.12	<0.13	<0.27	NA	0.043 J	0.13 J	0.48 J,B	0.37 J
Lithium, ug/L	NP*	7.7	40	<4.6	5.3 J	<4.6	<2.7	NA	<4.6	<4.6	<4.6	<2.7
Mercury, ug/L	DQ	DQ	2	<0.090	NA	<0.090	<0.10	NA	<0.090	NA	<0.090	<0.10
Molybdenum, ug/L	NP	14.7	100	4.2	4	4.6	5.2	NA	11.6	13.9	16.3	8.5
Selenium, ug/L	P*	0.28	50	0.14 J	<0.16	0.19 J	<1.0	NA	0.17 J	0.18 J	0.23 J	<1.0
Thallium, ug/L	NP*	0.35	2	<0.036	NA	<0.099	<0.27	NA	<0.036	NA	<0.099	<0.27
Radium 226/228 Combined, pCi/L	P	3.36	5	0.755	1.55	2.56	1.19	NA	0.987	0.969	0.819	0.815

Compliance Wells

Parameter Name	MW-301 10/16/2017	MW-301 5/9/2018	MW-301 8/13/2018	MW-301 10/10/2018	MW-301 3/12/2019	MW-301 4/3/2019	MW-302 10/17/2017	MW-302 5/9/2018	MW-302 8/13/2018	MW-302 10/10/2018	MW-302 3/12/2019	MW-302 4/3/2019
Appendix III												
Boron, ug/L	9,900 M1	9,140	12,800	8,040	NA	12,000	10,000	10,200	10,000	10,400	NA	12,000
Calcium, mg/L	140 M1	85.3	174	103	NA	150	231	231	210	219	NA	220
Chloride, mg/L	22.0	22.7	21.7	21.5	NA	21	16.4	14.1	14.7	13.5	NA	13
Fluoride, mg/L	0.27	0.36	0.52	0.26	NA	0.77	0.11 J	0.11 J	<0.063	<0.19	NA	0.37 J
Field pH, Std. Units	7.58	7.4	7.91	7.34	6.38	7.53	8.72	8.19	9.32	7.89	6.94	8.70
Sulfate, mg/L	454	188	187	358	NA	190	541	553	542	658	NA	510
Total Dissolved Solids, mg/L	780	568	960	656	NA	890	951	1,080	1,000	1,030	NA	1,000
Appendix IV												
Antimony, ug/L	NA	<0.026	<0.15	0.080 J	NA	<0.53	NA	<0.026	<0.15	0.082 J	NA	<0.53
Arsenic, ug/L**	NA	34.9	40.1	37.7	NA	42	NA	56.2	49.6	76.4	NA	53
Barium, ug/L	NA	198	420	276	NA	380	NA	363	340	180	NA	320
Beryllium, ug/L	NA	<0.012	<0.12	<0.089	NA	<0.27	NA	<0.012	<0.12	<0.089	NA	<0.27
Cadmium, ug/L	NA	0.040 J	<0.070	<0.033	NA	<0.077	NA	0.037 J	<0.070	0.040 J	NA	<0.077
Chromium, ug/L	NA	0.25 J,B	0.36 J	0.12 J	NA	<0.98	NA	0.22 J,B	0.33 J	0.097 J	NA	<0.98
Cobalt, ug/L	NA	0.15 J	0.45 J	0.10 J	NA	0.44 J	NA	0.19 J	0.15 J	0.18 J	NA	0.19 J
Fluoride, mg/L	NA	0.36	0.52	0.26	NA	0.77	NA	0.11 J	<0.063	<0.19	NA	0.37 J
Lead, ug/L	NA	0.17 J	0.13 J	<0.13	NA	<0.27	NA	0.17 J	<0.12	<0.13	NA	0.58
Lithium, ug/L	NA	17.8	18.9	24.5	NA	13	NA	65.4	61.4	57.8	59.9	56
Mercury, ug/L	NA	<0.090	NA	<0.090	NA	<0.10	NA	<0.090	NA	<0.090	NA	<0.10
Molybdenum, ug/L	NA	113	81.7	120	62.7	77	NA	118	121	122	123	100
Selenium, ug/L	NA	0.25 J	0.28 J	0.13 J	NA	<1.0	NA	0.25 J	0.22 J	0.23 J	NA	<1.0
Thallium, ug/L	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.036	NA	<0.099	NA	<0.27
Radium 226/228 Combined, pCi/L	NA	0.712	1.15	1.50	NA	1.15	NA	1.51	1.53	2.15	NA	0.872

Parameter Name	MW-303 10/17/2017	MW-303 5/9/2018	MW-303 8/13/2018	MW-303 10/10/2018	MW-303 3/12/2019	MW-303 4/3/2019	MW-304 10/17/2017	MW-304 5/9/2018	MW-304 8/13/2018	MW-304 10/10/2018	MW-304 3/12/2019	MW-304 4/3/2019
Appendix III												
Boron, ug/L	25,400	22,900	24,500	24,500	NA	22,000	5,580	5,140	5,440	6,180	NA	6,300
Calcium, mg/L	84.5	87.0	85.9	87.8	NA	86	103	107	102	88.5	NA	72
Chloride, mg/L	15.3	15.1	15.7	16.3	NA	15	46.5	58.1	25.9	50.3	NA	39
Fluoride, mg/L	0.25	0.22	0.44	0.27	NA	0.43 J	0.12 J	0.11 J	0.13 J	<0.19	NA	0.35 J
Field pH, Std. Units	8.59	7.51	8.03	7.10	6.46	7.79	9.52	8.51	7.6	9.01	6.94	8.56
Sulfate, mg/L	42.1	128	78.7	31.8	NA	120	248	273	188	271	NA	140
Total Dissolved Solids, mg/L	436	502	520	462	NA	540	540	657	551	537	NA	460
Appendix IV												
Antimony, ug/L	NA	<0.026	<0.15	<0.078	NA	<0.53	NA	0.75 J	0.3 J	0.77 J	NA	0.66 J
Arsenic, ug/L**	NA	7.9	52	29.8	NA	6.4	NA	57.2	45.4	58.3	NA	59
Barium, ug/L	NA	412	354	415	NA	440	NA	115	140	92	NA	90
Beryllium, ug/L	NA	<0.012	<0.12	<0.089	NA	<0.27	NA	<0.012	<0.12	<0.089	NA	<0.27
Cadmium, ug/L	NA	0.028 J	<0.070	<0.033	NA	<0.077	NA	<0.018	<0.070	0.054 J	NA	<0.077
Chromium, ug/L	NA	0.27 J,B	0.29 J	0.69 J	NA	<0.98	NA	0.22 J,B	0.34 J	0.091 J	NA	<0.98
Cobalt, ug/L	NA	0.31 J	0.46 J	0.62 J	NA	0.36 J	NA	0.098 J	<0.15	0.19 J	NA	0.11 J
Fluoride, mg/L	NA	0.22	0.44	0.27	NA	0.43 J	NA	0.11 J	0.13 J	<0.19	NA	0.35 J
Lead, ug/L	NA	0.21 J	0.22 J	0.54 J,B	NA	0.49 J	NA	<0.033	<0.12	<0.13	NA	<0.27
Lithium, ug/L	NA	50.7	42.1	35.8	51.6	52	NA	63.8	34.3	82.4	35.9	52
Mercury, ug/L	NA	<0.090	NA	<0.090	NA	<0.10	NA	<0.090	NA	<0.090	NA	<0.10
Molybdenum, ug/L	NA	75.4	77.9	56.5	NA	110	NA	126	74.9	113	47.4	58
Selenium, ug/L	NA	0.19 J	0.24 J	0.33 J	NA	<1.0	NA	0.24 J	0.21 J	0.26 J	NA	<1.0
Thallium, ug/L	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.036	NA	<0.099	NA	<0.27
Radium 226/228 Combined, pCi/L	NA	1.64	1.79	1.91	NA	1.26	NA	0.589	0.725	0.706	NA	0.408

4.4 — blue shaded cell indicates the compliance well result exceeds the UPL (background) and the Limit of Quantitation (LOQ).

30.8 — yellow highlighted cell indicates the compliance well result exceeds the GPS.

Abbreviations:

UPL = Upper Prediction Limit
NA = Not Analyzed
P = Parametric UPL with 1-of-2 retesting
GPS = Groundwater Protection Standard
DQ = Double Quantification Rule (not detected in background)
NP = Nonparametric UPL (highest background value)
LOD = Limit of Detection
LOQ = Limit of Quantification
mg/L = milligrams per liter
J = Estimated concentration at or above the LOD and below the LOQ.
B = Analyte was detected in the associated Method Blank.

D3= Sample was diluted due to the presence of high levels of non-target analytes or other matrix interference.
M1= Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.

* = UPL is below the LOQ for background sampling. For compliance wells, only results confirmed above the LOQ are evaluated as potential SSIs above background.
** = UPL for arsenic is greater than the MCL and will be used as the GPS.

Notes:

1. An individual result above the UPL or GPS does not constitute a statistically significant increase (SSI) above background or statistically significant level above the GPS. See the accompanying letter text for identification of statistically significant results.
2. GPS is the United States Environmental Protection Agency (US EPA) Maximum Contamination Level (MCL), if established, or the value from 40 CFR 257.95(h)(2), or the background UPL if it is higher.
3. Interwell UPLs calculated based on results from background wells MW-310 and MW-311.

Table 3. Groundwater Analytical Results Summary - CCR Program - Assessment Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25218201.00

Compliance Wells

Parameter Name	UPL Method	UPL	GPS	MW-305					MW-306					
				10/16/2017	5/9/2018	8/13/2018	10/10/2018	4/3/2019	10/16/2017	5/9/2018	8/14/2018	10/10/2018	3/11/2019	4/3/2019
Appendix III														
Boron, ug/L	NP	2,950		2,480	2,000	2,400	2,040	2,000	3,680	3,480	3,230	3,350	NA	2,900
Calcium, mg/L	P	210		92	82.5	103	93.2	83	35.3	32.0	33.5	34.6	NA	37
Chloride, mg/L	P	209		35.8	34.8	34.8	34.9	33	20.6	20.3	20.6	20.9	NA	21
Fluoride, mg/L	P	0.427		0.43	0.48	0.45	0.44	0.75	0.15 J	0.12 J	0.1 J	<0.19	NA	0.36 J
Field pH, Std. Units	P	8.17		7.78	7.72	7.81	7.29	7.80	10.66	6.80	10.33	6.04	6.27	6.69
Sulfate, mg/L	P	457		24.6	11.7	24.8	19.6	10	97.5	107	111	121	NA	110
Total Dissolved Solids, mg/L	P	1,113		437	441	542	490	470	301	396	303	289	NA	320
Appendix IV		**UPL**	**GPS**											
Antimony, ug/L	P*	0.17	6	NA	<0.026	<0.15	<0.078	<0.53	NA	1.2	1.4	1.2	NA	1.1
Arsenic, ug/L**	P	114.9	114.9	NA	0.28 J	0.39 J	0.44 J	<0.75	NA	52.6	48	50.6	NA	50
Barium, ug/L	P	1,147	2,000	NA	173	219	197	160	NA	13.6	15.5	14.8	NA	14
Beryllium, ug/L	NP*	0.036	4	NA	<0.012	<0.12	<0.089	<0.27	NA	<0.012	0.14 J	<0.089	NA	<0.27
Cadmium, ug/L	NP*	0.025	5	NA	<0.018	<0.070	<0.033	<0.077	NA	0.029 J	0.18 J	<0.033	NA	<0.077
Chromium, ug/L	P*	0.090	100	NA	0.25 J,B	0.21 J	0.27 J	<0.98	NA	0.24 J,B	0.25 J	0.18 J	NA	<0.98
Cobalt, ug/L	P	3.87	6	NA	0.14 J	<0.15	0.17 J	0.16 J	NA	0.035 J	0.18 J	<0.062	NA	<0.091
Fluoride, mg/L	P	0.427	4	NA	0.48	0.45	0.44	0.75	NA	0.12 J	0.1 J	<0.19	NA	0.36 J
Lead, ug/L	NP*	0.64	15	NA	0.034 J	<0.12	0.20 J,B	<0.27	NA	0.26 J	0.69 J	0.37 J,B	NA	<0.27
Lithium, ug/L	NP*	7.7	40	NA	27.8	33.6	27.6	29	NA	36.6	46.8	41.4	39.2	45
Mercury, ug/L	DQ	DQ	2	NA	<0.090	NA	<0.090	<0.10	NA	<0.090	NA	<0.090	NA	<0.10
Molybdenum, ug/L	NP	14.7	100	NA	0.87 J	1	0.72 J	<1.1	NA	84.7	82.9	83.5	NA	78
Selenium, ug/L	P*	0.28	50	NA	0.24 J	0.16 J	0.16 J	<1.0	NA	0.66 J	0.97 J	0.6 J	NA	<1.0
Thallium, ug/L	NP*	0.35	2	NA	<0.036	NA	<0.099	<0.27	NA	<0.036	NA	<0.099	NA	<0.27
Radium 226/228 Combined, pCI/L	P	3.36	5	NA	2.11	1.78	1.22	0.519	NA	0.482	1.04	1.10	NA	0.165

Parameter Name	MW-307						MW-308						MW-309					MW-312	MW-313
	10/16/2017	5/9/2018	8/14/2018	10/10/2018	3/11/2019	4/3/2019	10/17/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/17/2017	5/9/2018	8/14/2018	10/10/2018	4/3/2019	6/6/2019	6/6/2019
Appendix III																			
Boron, ug/L	3,920	3,910	4,090	3,720	NA	3,400	4,850	5,030	5,070	4,710	NA	4,300	4,400	4,720	4,930	4,720	4,200	6,100	7,400
Calcium, mg/L	31.3	27.3	27.2	27.6	NA	29	32.6	28.7	28.7	28.5	NA	32	101	83.6	74.1	72.4	73	67	110
Chloride, mg/L	20.8	20.1	20.1	21.6	NA	21	38.2	36.2	36.7	35.9	NA	38	85.4	112	111	105	100	27	85
Fluoride, mg/L	0.13 J	0.11 J	0.094 J	<0.19	NA	0.51	0.17 J	0.17 J	0.16 J	<0.19	NA	0.37 J	0.47	0.40	0.43	0.40	0.71	1.1	0.33 J
Field pH, Std. Units	10.46	10.3	10.12	9.88	9.71	10.39	9.75	9.75	9.86	9.82	7.72	9.97	8.50	7.25	7.39	7.46	7.45	6.99	6.94
Sulfate, mg/L	126	119	119	143	NA	120	177	164	167	193	NA	170	149	107	98.9	111	78	220	210
Total Dissolved Solids, mg/L	341	347	340	336	NA	420	472	494	468	440	NA	490	671	688	668	650	650	540	700
Appendix IV																			
Antimony, ug/L	NA	0.50 J	0.58 J	0.62 J	NA	<0.53	NA	0.32 J	0.32 J	0.36 J	NA	<0.53	NA	<0.026	<0.15	<0.078	<0.53	<0.53	<0.53
Arsenic, ug/L**	NA	54.3	52.3	52.8	NA	43	NA	79.1	82.5	79.5	NA	78	NA	28.2	33.3	35.6	30	14	5.5
Barium, ug/L	NA	32.3	29	31.1	NA	29	NA	64.3	67.1	66.5	NA	70	NA	154	180	194	130	160	510
Beryllium, ug/L	NA	<0.012	<0.12	<0.089	NA	<0.27	NA	<0.012	<0.12	<0.089	NA	<0.27	NA	0.012 J	<0.12	<0.089	<0.27	<0.27	<0.27
Cadmium, ug/L	NA	0.12 J	<0.070	0.068 J	NA	<0.077	NA	0.020 J	<0.070	0.058 J	NA	<0.077	NA	0.021 J	<0.070	<0.033	<0.077	<0.077	<0.077
Chromium, ug/L	NA	0.27 J,B	0.36 J	0.15 J	NA	<0.98	NA	0.25 J,B	<0.19	0.16 J	NA	<0.98	NA	0.32 J,B	0.22 J	0.18 J	<0.98	<0.98	<0.98
Cobalt, ug/L	NA	0.033 J	<0.15	<0.062	NA	<0.091	NA	0.057 J	<0.15	0.074 J	NA	<0.091	NA	4.9	0.82 J	0.68 J	1.3	0.65	0.41 J
Fluoride, mg/L	NA	0.11 J	0.094 J	<0.19	NA	0.51	NA	0.17 J	0.16 J	<0.19	NA	0.37 J	NA	0.40	0.43	0.40	0.71	1.1	0.33 J
Lead, ug/L	NA	0.39 J	0.43 J	0.49 J,B	NA	0.37 J	NA	0.25 J	0.27 J	0.45 J,B	NA	<0.27	NA	0.045 J	<0.12	<0.13	<0.27	0.54	<0.27
Lithium, ug/L	NA	47.8	56.1	45.4	50.7	50	NA	46.0	52.0	43.6	48.9	50	NA	<4.6	<4.6	<4.6	3.3 J	24	43
Mercury, ug/L	NA	<0.090	NA	<0.090	NA	<0.10	NA	<0.090	NA	<0.090	NA	<0.10	NA	<0.090	NA	<0.090	<0.10	<0.10	<0.10
Molybdenum, ug/L	NA	154	155	159	156	100	NA	140	140	145	135	110	NA	43.4	52.8	71.8	47	290	130
Selenium, ug/L	NA	0.36 J	0.41 J	0.36 J	NA	<1.0	NA	0.31 J	0.43 J	0.4 J	NA	<1.0	NA	0.30 J	0.31 J	0.29 J	<1.0	<1.0	<1.0
Thallium, ug/L	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.036	NA	<0.099	<0.27	<0.27	<0.27
Radium 226/228 Combined, pCI/L	NA	0.0587	0.415	1.43	NA	0.447	NA	0.283	0.0726	0.334	NA	0.328	NA	0.218	0.96	1.05	0.42	NA	NA

4.4 blue shaded cell indicates the compliance well result exceeds the UPL (background) and the Limit of Quantitation (LOQ).

30.8 yellow highlighted cell indicates the compliance well result exceeds the GPS.

Abbreviations:
UPL = Upper Prediction Limit
NA = Not Analyzed
P = Parametric UPL with 1-of-2 retesting
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Notes:
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3. Interwell UPLs calculated based on results from background wells MW-310 and MW-311.

Created by: NDK Date: 5/1/2018
Last revision by: NDK Date: 7/24/2019
Checked by: MDB Date: 7/25/2019

I:\25218201.00\Deliverables\BGS ACM\Tables\[3_CCR GW Screening Summary_BGS_UPL_GPS_reformatted.xlsx]Table

Table 4. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25218201.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill
CORRECTIVE ACTION ASSESSMENT - 40 CFR 257.97(b)					
257.97(b)(1) Is remedy protective of human health and the environment?	No	Yes	Yes	Yes	Yes
257.97(b)(2) Can the remedy attain the groundwater protection standard?	Unlikely	Yes	Yes	Yes	Yes
257.97(b)(3) Can the remedy control the source(s) of releases so as to reduce or eliminate, to the maximum extent feasible, further releases of constituents in appendix IV to this part into the environment?	No	Yes	Yes	Yes	Yes
257.97(b)(4) Can the remedy remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible?	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR
257.97(b)(5) Can the remedy comply with standards for management of wastes as specified in §257.98(d)?	Not Applicable	Yes	Yes	Yes	Yes
LONG- AND SHORT-TERM EFFECTIVENESS - 40 CFR 257.97(c)(1)					
257.97(c)(1)(i) Magnitude of reduction of existing risks	No reduction of existing risk	Existing risk reduced by achieving GPS	Same as Alternative #2	Same as Alternative #2	Same as Alternative #2
257.97(c)(1)(ii) Magnitude of residual risks in terms of likelihood of further releases due to CCR remaining following implementation of a remedy	No reduction of existing risk. Residual risk is limited for all alternatives due to limited extent of impacts and lack of receptors.	Magnitude of residual risk of further releases is lower than current conditions due to final cover eliminating infiltration through CCR; Residual risk is limited for all alternatives due to limited extent of impacts and lack of receptors	Same as Alternative #2 with potential further reduction in release risk due to CCR material footprint; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts	Same as Alternative #3 with potential further reduction in release risk due to composite liner and cover; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts	Same as Alternative #3 with potential further reduction in release risk due to removal of CCR from site; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts
257.97(c)(1)(iii) The type and degree of long-term management required, including monitoring, operation, and maintenance	Not Applicable	30-year post-closure groundwater monitoring; Groundwater monitoring network maintenance and as-needed repair/replacement; Final cover maintenance (e.g., mowing and as-needed repair); Periodic final cover inspections; Additional corrective action as required based on post-closure groundwater monitoring	Same as Alternative #2	Same as Alternative #2	No on-site long-term management required; Limited on-site post-closure groundwater monitoring until GPS are achieved; Receiving disposal facility will have same/similar long-term monitoring, operation, and maintenance requirements as Alternative #2

Table 4. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25218201.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill
LONG- AND SHORT-TERM EFFECTIVENESS - 40 CFR 257.97(c)(1) (continued)					
257.97(c)(1)(iv) Short-term risks - Implementation					
Excavation	None	Limited risk to community and environment due to limited amount of excavation (<100K cy) required to establish final cover subgrades and no off-site excavation	Same as Alternative #2 with increased risk to environment due to increased excavation volumes (>100K cy, <300K cy) required for consolidation	Same as Alternative #3 with increased risk to environment due to increased excavation volumes (>1M cy) and temporary CCR storage during disposal site construction required for removal and on-site re-disposal	Same as Alternative #4 with reduced risk to environment from excavation due to limited on-site storage
Transportation	None	No risk to community or environment from off-site CCR transportation; Typical risk due to construction traffic delivering final cover materials to site	Same as Alternative #2 with reduced risk from construction traffic due to reduced final cover material requirements (smaller cap footprint)	Same as Alternative #2 with increased risk from construction traffic due to increased material import requirements (liner and cap construction required)	Highest level of community and environmental risk due to CCR volume export (>1M cy)
Re-Disposal	None	Limited risk to community and environment due to limited volume of CCR re-disposal (<100K cy)	Same as Alternative #2 with increased risk to environment due to increased excavation volumes (>100K cy, <300K cy) required for consolidation	Same as Alternative #3 with increased risk to environment due to increased excavation volumes (>1M cy) and temporary CCR storage during disposal site construction required for removal and on-site re-disposal	Same as Alternative #4 with increased risk to community and environment due to re-disposal of large CCR volume (>1M cy) at another facility; Re-disposal risks are managed by the receiving disposal facility
257.97(c)(1)(v) Time until full protection is achieved	Unknown	To be evaluated further during remedy selection. Closure and capping anticipated by end of 2022. Groundwater protection timeframe to reach GPS potentially 2 to 10 years following closure construction, achievable within 30-year post-closure monitoring period.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential for decrease in time to reach GPS due to consolidation of CCR.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential decrease in time to reach GPS due to source isolation within liner/cover system.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential decrease in time to reach GPS due to impounded CCR source removal.
257.97(c)(1)(vi) Potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, re-disposal, or containment	No change in potential exposure	Potential for exposure is low. Remaining waste is capped.	Same as Alternative #2	Same as Alternative #2	No potential for on-site exposure to remaining waste since no waste remains on site; Risk of potential exposure is transferred to receiving disposal facility and is likely similar to Alternative #2
257.97(c)(1)(vii) Long-term reliability of the engineering and institutional controls	Not Applicable	Long-term reliability of cap is good; Significant industry experience with methods/ controls; Capping is common practice/industry standard for closure in place for remediation and solid waste management	Same as Alternative #2 with potentially increased reliability due to smaller footprint and reduced maintenance	Same as Alternative #3	Success of remedy at BGS does not rely on long-term reliability of engineering or institutional controls; Overall success relies on reliability of the engineering and institutional controls at the receiving facility.
257.97(c)(1)(viii) Potential need for replacement of the remedy	Not Applicable	Limited potential for remedy replacement if maintained; Some potential for remedy enhancement due to residual groundwater impacts following source control	Same as Alternative #2 with reduced potential need for remedy enhancement with consolidated/smaller closure area footprint	Same as Alternative #2 with further reduction in potential need for remedy enhancement composite with liner	No on-site potential for remedy replacement; Limited potential for remedy enhancement due to residual groundwater impacts following source control

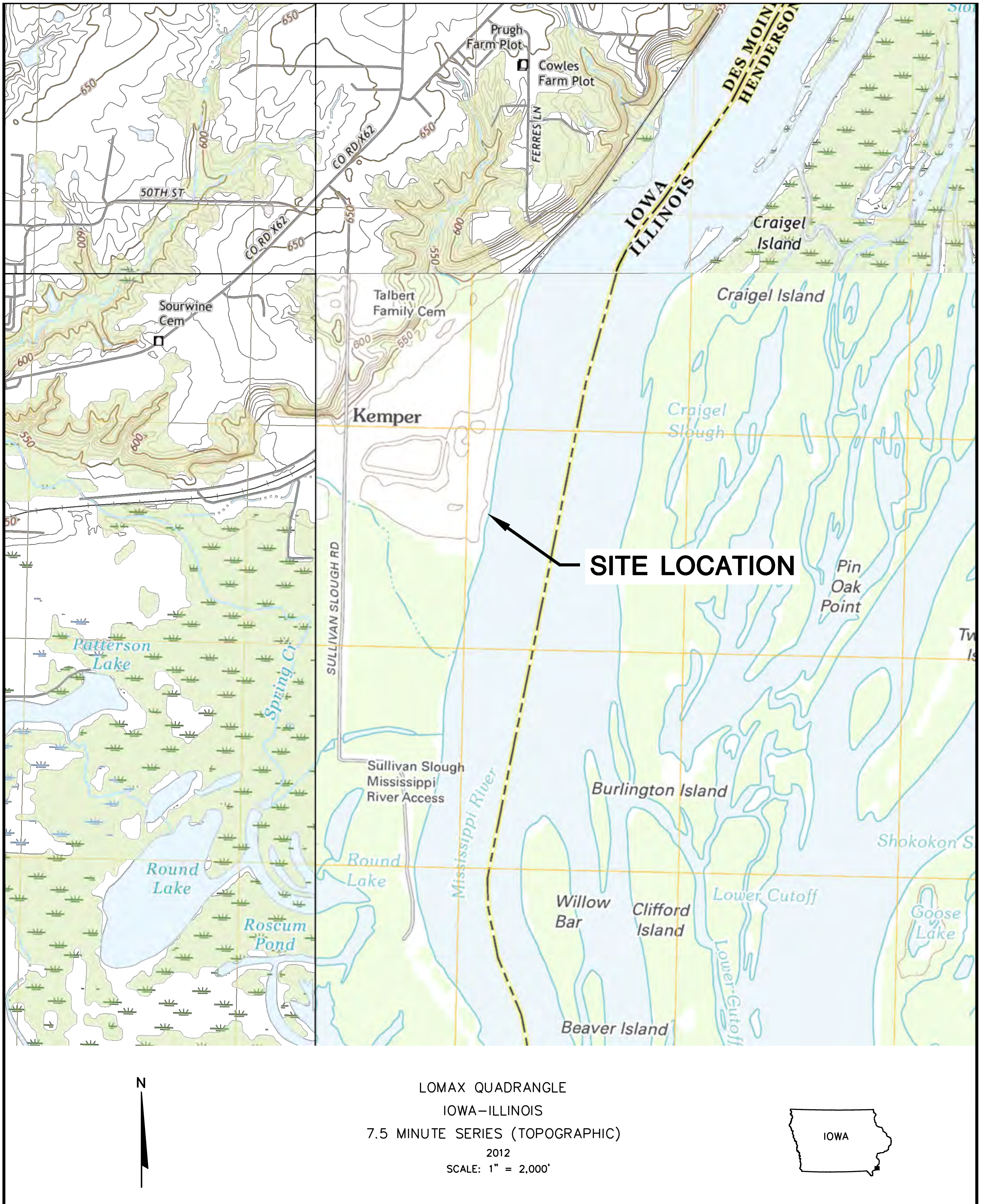
Table 4. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25218201.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill
SOURCE CONTROL TO MITIGATE FUTURE RELEASES - 40 CFR 257.97(c)(2)					
257.97(c)(2)(i) The extent to which containment practices will reduce further releases	No reduction in further releases	Cap will reduce further releases by minimizing infiltration through CCR	Same as Alternative #2 with further reduction due to consolidated/smaller closure footprint	Same as Alternative #3 with further reduction due to composite liner and 5-foot groundwater separation required by CCR Rule	Removal of CCR prevents further releases at BGS; Receiving disposal site risk similar to Alternative #3
257.97(c)(2)(ii) The extent to which treatment technologies may be used	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies
IMPLEMENTATION - 40 CFR 257.97(c)(3)					
257.97(c)(3)(i) Degree of difficulty associated with constructing the technology	Not Applicable	Low complexity construction; Potentially lowest level of dewatering effort - dewatering required for cap installation only	Low complexity construction; Moderate degree of logistical complexity; Moderate to low level of dewatering effort - dewatering required for material excavation/placement and capping	Moderate complexity construction due to composite liner and cover; High degree of logistical complexity due to excavation and on-site storage of >1M cy of CCR while new lined disposal area is constructed; Moderate to high level of dewatering effort - dewatering required for excavation of full CCR volume	Low complexity construction; High degree of logistical complexity including the excavation and off-site transport of >1M cy of CCR and permitting/development of off-site disposal facility airspace; Moderate to high level of dewatering effort - dewatering required for excavation of full CCR volume
257.97(c)(3)(ii) Expected operational reliability of the technologies	Not Applicable	High reliability based on historic use of capping as corrective measure	Same as Alternative #2	Same as Alternative #2	Success at BGS does not rely on operational reliability of technologies; Overall success relies on off-site disposal facility, which is likely same/similar to Alternative #2
IMPLEMENTATION - 40 CFR 257.97(c)(3) (continued)					
257.97(c)(3)(iii) Need to coordinate with and obtain necessary approvals and permits from other agencies	Not Applicable	Need is moderate in comparison to other alternatives State Closure Permit required; Federal/State/Local Floodplain permitting required; State and local erosion control/construction stormwater management permits required; Federal/State wetland permitting potentially required	Need is lowest in comparison to other alternatives; State Closure Permit required; State and local erosion control/construction stormwater management permits required; Federal/State/Local Floodplain permitting likely required	Need is high in comparison to other alternatives State Closure Permit required; State Landfill Permit may be required; Federal/State/Local Floodplain permitting likely required; State and local erosion control/construction stormwater management permits required; Federal/State wetland permitting likely required	Need is highest in comparison to other alternatives; State Closure Permit required; State and local erosion control/construction stormwater management permits required; Approval of off-site disposal site owner required; May require State solid waste comprehensive planning approval; Federal/State/Local Floodplain permitting likely required; Federal/State wetland permitting likely required; Local road use permits likely required
257.97(c)(3)(iv) Availability of necessary equipment and specialists	Not Applicable	Necessary equipment and specialists are highly available; Highest level of demand for cap construction material	Same as Alternative #2; Lowest level of demand for cap construction material	Same as Alternative #2; Moderate level of demand for liner and cap construction material	Availability of necessary equipment to develop necessary off-site disposal facility airspace and transport >1M cy of CCR to new disposal facility will be a limiting factor in the schedule for executing this alternative; No liner or cover material demands for on-site implementation of remedy
257.97(c)(3)(v) Available capacity and location of needed treatment, storage, and disposal services	Not Applicable	Capacity and location of treatment, storage, and disposal services is not a factor for this alternative	Capacity and location of treatment, storage, and disposal services is unlikely to be a factor for this alternative	Available temporary on-site storage capacity for >1M cy of CCR while composite liner is constructed is significant limiting factor	off-site disposal capacity, facility logistical capacity, or the time required to develop the necessary off-site disposal and logistical capacity is a significant limiting factor.
COMMUNITY ACCEPTANCE - 40 CFR 257.97(c)(4)					
257.97(c)(4) The degree to which community concerns are addressed by a potential remedy (Anticipated)	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed

Created by: LAB/SK Date: 6/20/2019
Last revision by: EJN Date: 7/31/2019
Checked by: TK Date: 9/12/2019

I:\25218201.00\Deliverables\BGS ACM\Tables\[4_Prelim Evaluation of Corrective Measure Alternatives_BGS.xlsx]BGS_Evaluation Matrix

Figures



CLIENT	ALLIANT ENERGY 4902 N. BILTMORE LANE, #1000 MADISON, WI 53718	SITE	ALLIANT ENERGY BURLINGTON GENERATING STATION BURLINGTON, IOWA	SITE LOCATION MAP

PROJECT NO.	25219066.00	DRAWN BY:	AHB	ENGINEER	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	FIGURE
DRAWN:	05/29/15	CHECKED BY:	KAK			1
REVISED:	06/19/19	APPROVED BY:	TK 09/10/19			

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LEGEND

EXISTING MONITORING WELL LOCATION

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW301, MW302, AND MW309-MW311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-301 THROUGH MW-311 WERE SURVEYED BY FRENCH-RENEKER ASSOCIATES OF FRANKLIN, IA ON MARCH 16, 2016.
4. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.

N

300 0 300

SCALE: 1" = 300'

PROJECT NO.	25219066.00	DRAWN BY:	AHB/BSS/ LEC	ENGINEER	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	CLIENT	ALLIANT ENERGY 4902 N. BILTMORE LANE, #1000 MADISON, WI 53718	SITE	ALLIANT ENERGY BURLINGTON GENERATING STATION BURLINGTON, IOWA	SITE PLAN AND MONITORING WELL LOCATIONS	FIGURE 2
DRAWN:	04/01/16	CHECKED BY:	NK								
REVISED:	06/19/19	APPROVED BY:	TK 09/10/19								

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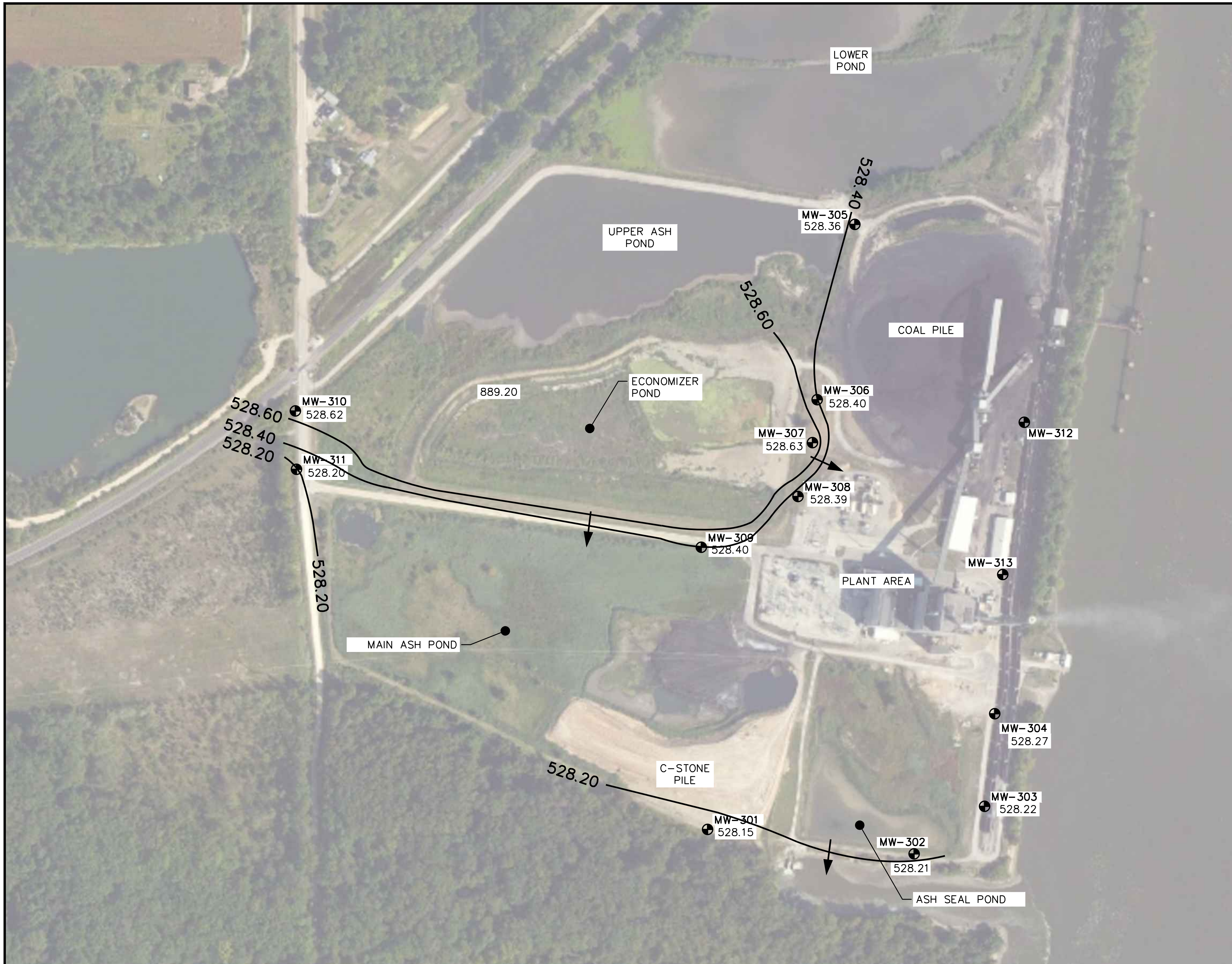
11/25/2020 - Classification: Internal - ECRM7803923



LEGEND

- EXISTING MONITORING WELL LOCATION
- WATER TABLE ELEVATION CONTOUR
- APPROXIMATE FLOW DIRECTION

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15–17, 2015.
2. MONITORING WELLS MW301, MW302, AND MW309–MW311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-301 THROUGH MW-311 WERE SURVEYED BY FRENCH–RENEKER ASSOCIATES OF FRANKLIN, IA ON MARCH 16, 2016.
4. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
5. WATER TABLE ELEVATION ESTIMATED BASED ON MONITORING WELLS SCREENED BELOW THE WATER TABLE IN THE SAND UNIT.

PROJECT NO.	25219066.00	DRAWN BY:	BSS/LEC
DRAWN:	06/18/19	CHECKED BY:	NK
REVISED:	07/17/19	APPROVED BY:	TK 09/10/19

ENGINEER: SCS ENGINEERS, 2830 DAIRY DRIVE MADISON, WI 53718-6751, PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY, 4902 N. BILTMORE LANE, #1000, MADISON, WI 53718

SITE: ALLIANT ENERGY, BURLINGTON GENERATING STATION, BURLINGTON, IOWA

WATER TABLE MAP
APRIL 3, 2019

FIGURE 3

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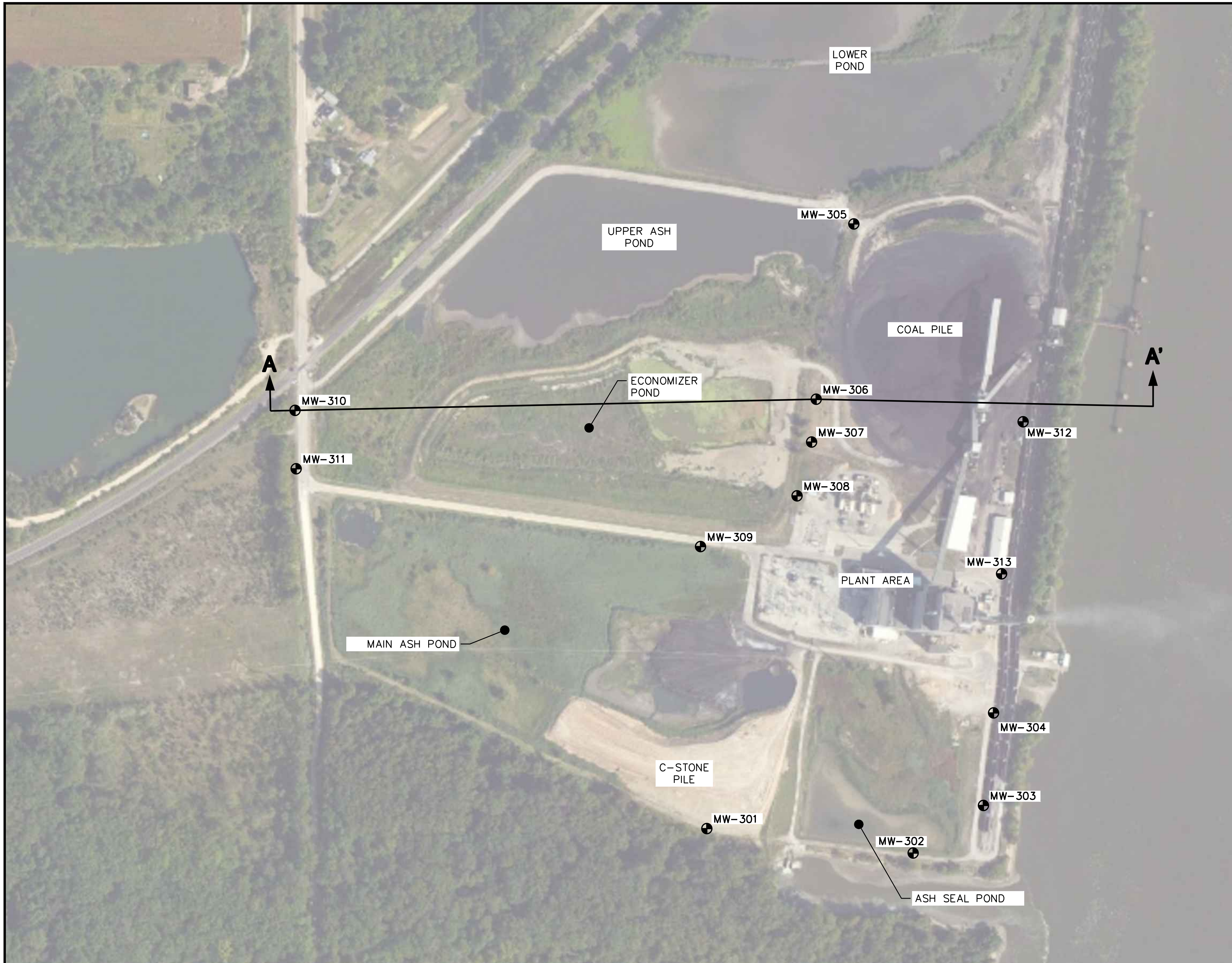

LEGEND

EXISTING MONITORING WELL LOCATION

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW301, MW302, AND MW309-MW311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
5. MONITORING WELLS MW-301 THROUGH MW-311 WERE SURVEYED BY FRENCH-RENEKER ASSOCIATES OF FRANKLIN, IA ON MARCH 16, 2016.
6. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.

N

300 0 300

SCALE: 1" = 300'

PROJECT NO.	25219066.00	DRAWN BY:	AHB/BSS
DRAWN:	06/12/19	CHECKED BY:	NK
REVISED:	06/12/19	APPROVED BY:	TK 09/10/19

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY
4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

SITE PLAN AND CROSS SECTION LOCATION MAP

FIGURE 4

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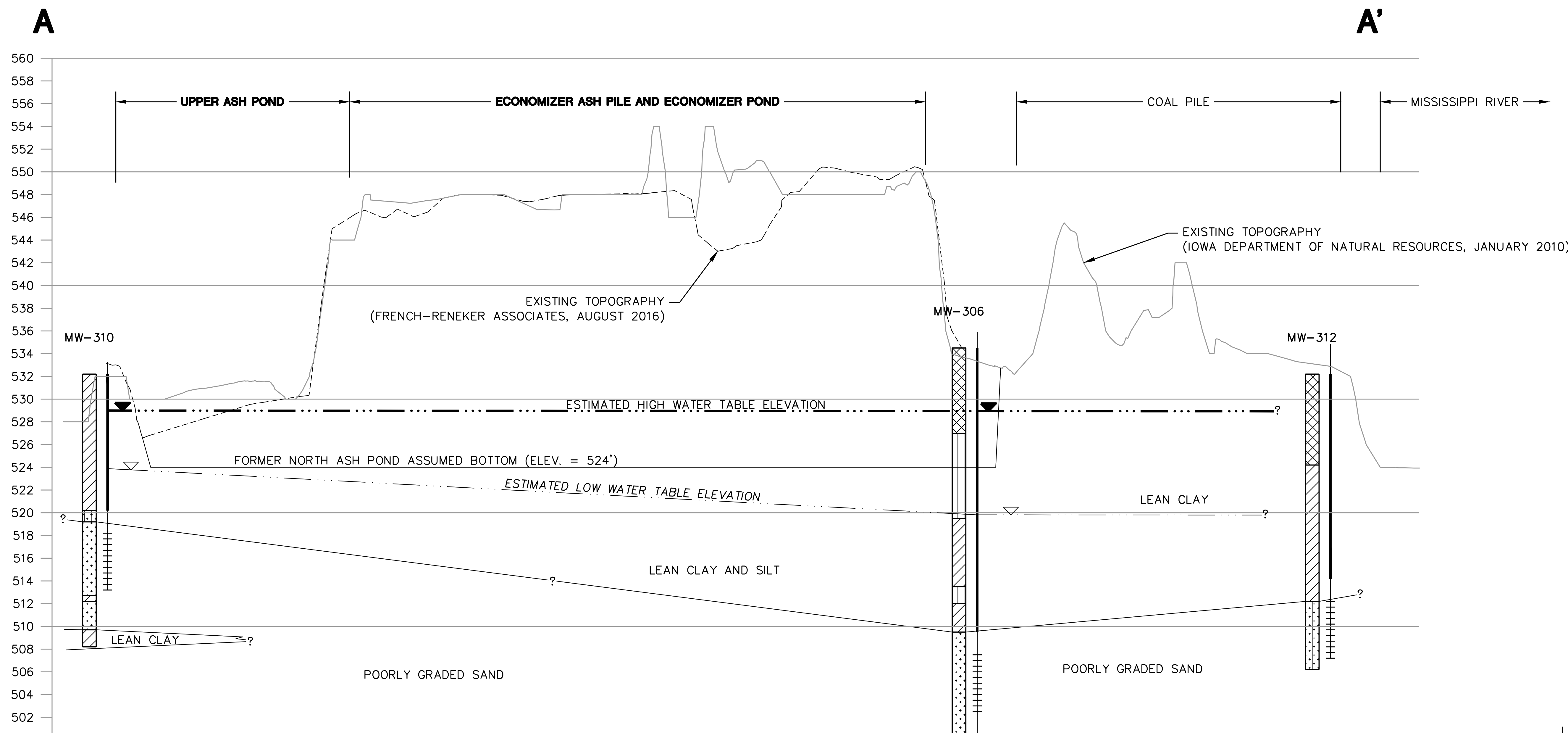


NOTES:

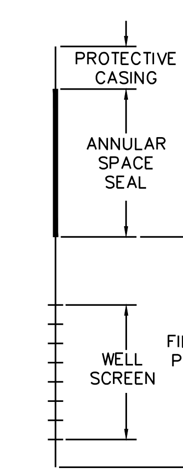
1. UPPER ASH POND BOTTOM ELEVATION IS BASED ON THE EMBANKMENT CREST ELEVATION (531 FEET) AND INTERNAL STORAGE DEPTH (7 FEET) REPORTED IN THE HISTORY OF CONSTRUCTION REPORT, REVISION 1 ISSUED MARCH 6, 2018, BY HARD HAT SERVICES.
2. THE BOTTOM ELEVATION OF THE ECONOMIZER POND IS ASSUMED TO BE THE SAME AS THE UPPER ASH POND (524 FEET). THE ECONOMIZER POND WAS CONSTRUCTED IN THE ORIGINAL FOOTPRINT OF THE NORTH ASH POND PER THE HISTORY OF CONSTRUCTION REPORT, REVISION 1, ISSUED MARCH 6, 2018, BY HARD HAT SERVICES.
3. ESTIMATED WATER TABLE ELEVATION IS BASED ON WATER LEVELS IN MONITORING WELLS SCREENED BELOW THE WATER TABLE IN THE SAND UNIT.
4. MW-306 AND MW-312 WERE HYDROVACED TO APPROXIMATELY 8 FEET. HYDROVACING IS PERFORMED TO DETERMINE IF UNDERGROUND UTILITIES ARE PRESENT. HIGH PRESSURE WATER AND A VACUUM ARE USED TO CLEAR THE BOREHOLE. AFTER HYDROVACING WAS COMPLETE THE BOREHOLE WAS FILLED WITH SAND TO COMPLETE THE BOREHOLE DRILLING PROCESS.

LEGEND

- HYDROVAC FILL SAND
- SAND, POORLY GRADED, LITTLE OR NO FINES (SP)
- SILT (ML)
- LEAN CLAY (CL)
- SILTY SAND (SM)
- WATER LEVEL AT MONITORING WELL, APRIL 2019
- WATER LEVEL AT MONITORING WELL, AUGUST 2017

0 200

HORIZONTAL SCALE: 1" = 200'
VERTICAL SCALE: 1" = 10'
VERTICAL EXAGGERATION = 20X



WELL DETAIL

PROJECT NO. 25219066.00	DRAWN BY: KP	ENGINEER: SCS ENGINEERS, 2830 DAIRY DRIVE MADISON, WI 53718-6751, PHONE: (608) 224-2830	CLIENT: ALLIANT ENERGY, 4902 N. BILTMORE LANE, #1000, MADISON, WI 53718	SITE: ALLIANT ENERGY, BURLINGTON GENERATING STATION, BURLINGTON, IOWA	GEOLOGIC CROSS SECTION	FIGURE 5
DRAWN: 06/12/19	CHECKED BY: NK					
REVISED: 07/17/19	APPROVED BY: TK 09/10/19					

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Appendix A

Regional Geological and Hydrogeological Information

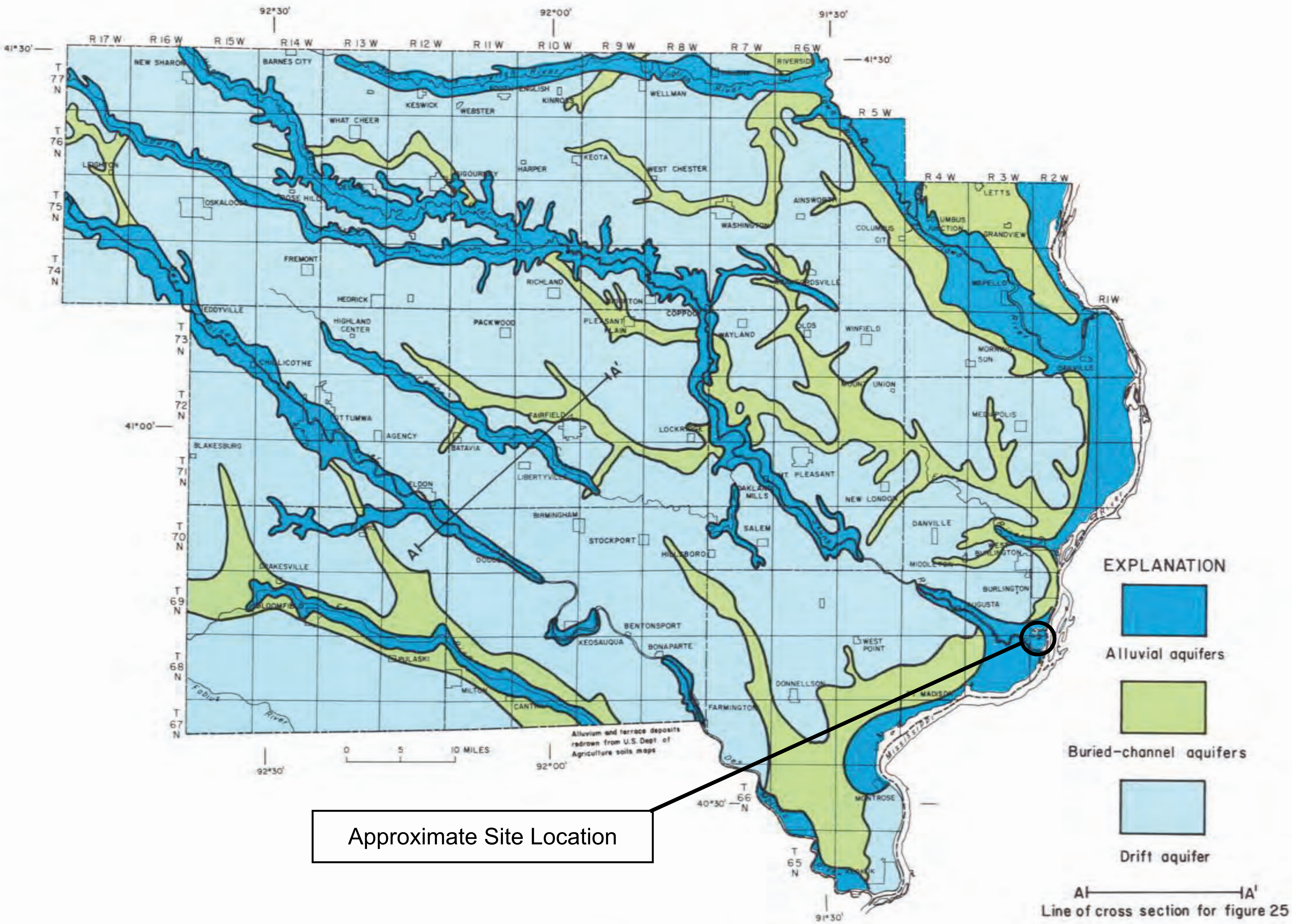

Figure 24.—Areal distribution of surficial aquifers

Source: Coble, R.W., The Water Resources of Southeast Iowa, Iowa Geological Survey Water Atlas Number 4, 1971.

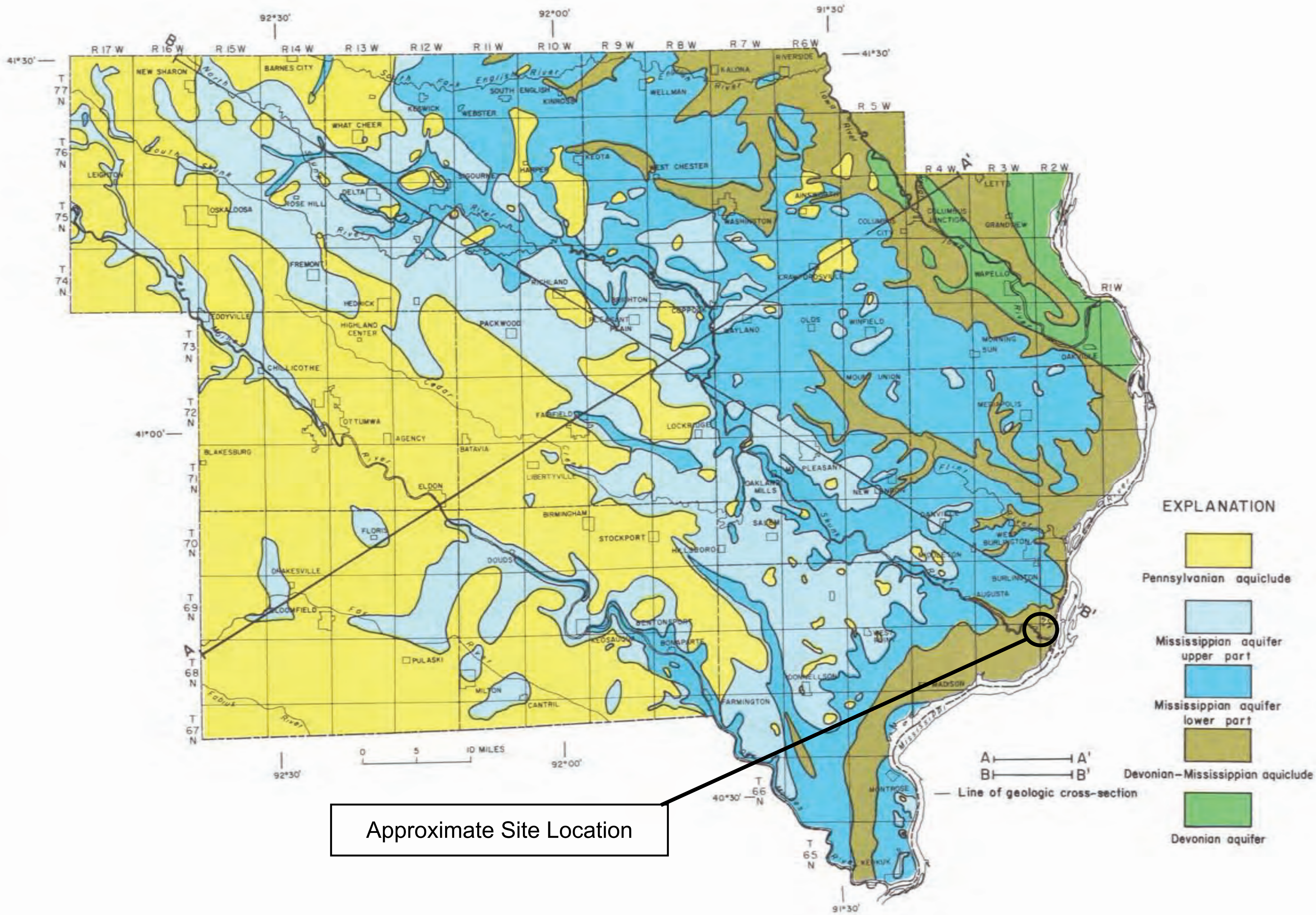

Figure 27.—Bedrock hydrogeologic map

Source: Coble, R.W., The Water Resources of Southeast Iowa, Iowa Geological Survey Water Atlas Number 4, 1971.

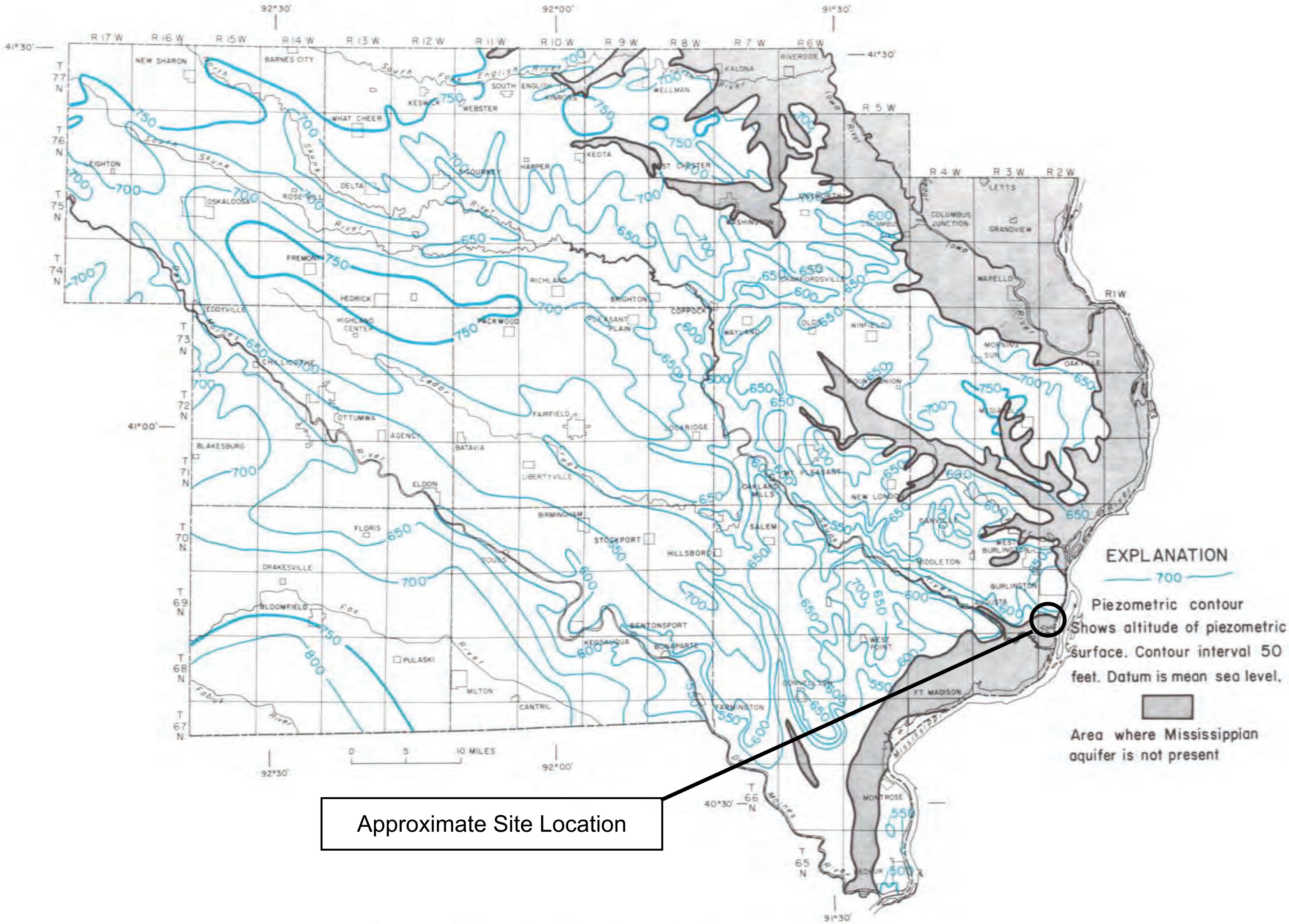

Figure 41.—Altitude of the water levels in wells tapping the Mississippian aquifer

Source: Coble, R.W., The Water Resources of Southeast Iowa, Iowa Geological Survey Water Atlas Number 4, 1971.

Appendix B

Boring Logs

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-301

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	2/29/2016	2/29/2016	Direct Push 4-1/2/HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-301	Feet	536.0 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,382 N, 2,300,041 E S/C/N
SW 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W

Lat ___ ° ___ ' ___ "
Long ___ ° ___ ' ___ "

Local Grid Location
Feet ☐ N ☐ S
Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample: Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
			10	LEAN CLAY WITH SAND, very dark gray (10YR 3/1).	CL									
S1	16		11							W				
S2	45		14							W				
			15											

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm: SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-301

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			16, 17	LEAN CLAY WITH SAND, very dark gray (10YR 3/1). *(continued)*	CL									
S3	37		18, 19	POORLY GRADED SAND, very dark gray (10YR 3/1).	SP					W				
			20, 21	SILT WITH SAND, very dark gray (10YR 3/1).	ML									
				POORLY GRADED SAND, very dark gray (10YR 3/1).	SP									
S4	24		22, 23, 24	SANDY SILT, very dark gray (10YR 3/1).	MLS					W				
S5	NA		25, 26, 27, 28, 29	POORLY GRADED SAND, very dark gray (10YR 3/1).	SP					W				Recovery NA sleeve stuck in discrete sampler.
				End of Boring at 29.50 feet bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-302

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	2/29/2016	2/29/2016	Direct Push 4-1/2/HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-302	Feet	533.2 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,310 N, 2,300,647 E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' "
Long ° ' "
Local Grid Location
Feet ☐ N ☐ S
Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
S1	15		10–12	POORLY GRADED SAND WITH SILT, medium grained, very dark gray (10YR 3/1).	SP-SM					W				
S2	15		12–15	POORLY GRADED SAND, medium grained, very dark gray (10YR 3/1).	SP					W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

Firm SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-302

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			16	POORLY GRADED SAND, medium grained, very dark gray (10YR 3/1). *(continued)*	SP									
S3	17		17–19	LEAN CLAY, very dark gray (10YR 3/1).	CL					W				
S4	15		20–23	POORLY GRADED SAND, coarse grained, very dark gray (10YR 3/1).	SP					W				
S5	16		24–27							W				
			28	End of Boring at 28 feet bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐ Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-303

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/15/2015	12/15/2015	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-303	Feet	531.0 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,450 N, 2,300,854 E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' "
Long ° ' "
Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled	FILL									
			10	LEAN CLAY, dark gray (10YR 3/1).	CL									
S1	0	4 6 8 8	11											Rock in the end of shoe.
S2	14	2 4 4 5	13–14							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: 608-224-2830 Fax:

Boring Number MW-303

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
				LEAN CLAY, dark gray (10YR 3/1). *(continued)*	CL									
S3	15	2 2 4 6	16							W				
			17											
			18											
S4	3	1 2 3 8	19							W				Rock in the end of shoe.
			20	POORLY GRADED SAND, coarse grained, very dark gray (2.5Y 3/1), some gravel.	SP									
S5	10	4 8 9 9	21							W				
			22											
			23	POORLY GRADED SAND, very dark gray (2.5Y 3/1), medium grained.	SP									
S6	14	1 2 8 9	24							W				
			25											
S7	8	4 6 8 10	26	same as above except, coarse grained						W				
			27	End of Boring at 27.50 ft bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-304

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/15/2015	12/15/2015	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-304	Feet	532.2 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,721 N, 2,300,883 E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample: Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled	FILL									
			10–15	FAT CLAY, dark gray (10YR 3/1)	CH									
S1	12	3 4 11 14	11							W				
S2		2 3 5 5	14							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm: SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-304

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
S3	14	1 1 2 4	16–17	SANDY SILT, very dark gray (2.5Y 3/1), fine grained.	ML					W				
S4	14	1 2 3	18–19	POORLY GRADED SAND, very dark gray (2.5Y 3/1), medium grained.	SP					W				
S5	24	2 3 5 8	20–22							W				
S6	12	3 5 6 7	23–24	Same as above except, coarse grained.						W				
S7	12	3 6 11 16	25–27							W				
			27	End of boring at 27 feet bgs										

SCS ENGINEERS — Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐ Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-305

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/17/2015	12/17/2015	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-305	Feet	530.9 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 280,157 N, 2,300,473 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ___ ° ___ ' ___ " Long ___ ° ___ ' ___ "
Local Grid Location: ☐ N Feet ☐ S ☐ E Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–5	FILL, boring location was cleared to 5' bgs by hydrovac, then back filled.	FILL									
			5	SILT, ash, black (2.5Y 2.5/1), (fill).	ML									
S1	14	13 30 20 12	6							M				
S2	6	3 4 2 1	8.5							M				
			10	LEAN CLAY, olive (5Y 4/4).	CL									
S3	5	4 4 6 7	11							M				
			13	same as above except, black (2 5Y 2.5/1).										
S4	10	2 4 6 8	13.5							M				
			15											

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: 608-224-2830 Fax:

Boring Number MW-305

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
				LEAN CLAY, olive (5Y 4/4). *(continued)*	CL									
S5	14	1 1 2 3	16											
			17											
			18	same as above except, very dark gray (10YR 3/1).										
S6	16	1 1 2 2	19											
			20	POORLY GRADED SAND, very dark gray (10YR 3/1), coarse grained.	SP									
S7	12	1 2 4 5	21							W				
			22											
			23											
S8	12	1 1 2 3	24							W				
			25											
S9	8		26							W				
			27											
				End of Boring at 27.50 ft bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-306

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/16/2015	12/17/2015	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-306	Feet	534.5 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,643 N, 2,300,362 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ___ ° ___ ' ___ "
Long ___ ° ___ ' ___ "
Local Grid Location: ☐ N ☐ E; Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–7.5	FILL, boring location was cleared to 7.5' bgs by hydrovac, then back filled	FILL									
			7.5–15	SANDY SILT, very dark gray (2 5Y 3/1), fine grained sand	ML									
S1	22	6 8 12 12	8–10											
S2	22	7 2 2 2	10.5–12.5							W				
S3	12	4 9 19 21	13–15							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: 608-224-2830 Fax:

Boring Number MW-306

Sample Number and Type	Sample Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
				LEAN CLAY, black (2.5Y 2.5/1).	CL									
S4	10	2 2 2 2	16							W				
			17											
			18											
S5	10	1 1 1 2	19							W				
			20											
S6	22	3 4 5	21	SANDY SILT, very dark gray (2.5 3/1), fined grained sand.	ML					W				
			22											
				LEAN CLAY, black (2.5Y 2.5/1).	CL									
S7	10	1 1 1 2	23–24							W				
			25	POORLY GRADED SAND, very dark gray (2.5Y 3/1), coarse grained.	SP									
S8	20	2 3 6 10	26							W				
			27											
S9	10	1 3 3 5	28–29							W				
			30											
S10	10	2 2 3 8	31							W				
			32											
			33											
			34	End of boring at 34 ft bgs										

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SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name: IPL- Burlington Generating Station SCS#: 25215135.80		License/Permit/Monitoring Number:		Boring Number: MW-307	
Boring Drilled By: Name of crew chief (first, last) and Firm: Mike Mueller, Cascade Drilling		Date Drilling Started: 12/16/2015	Date Drilling Completed: 12/16/2015	Drilling Method: 4-1/2 hollow stem auger	
Unique Well No.:	DNR Well ID No.:	Common Well Name: MW-307	Final Static Water Level: Feet	Surface Elevation: 534.3 Feet	Borehole Diameter: 8.5 in
Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒ State Plane 279,517 N, 2,300,349 E S/C/N; NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W		Lat ° ' " Long ° ' "		Local Grid Location: ☐ N Feet ☐ S; ☐ E Feet ☐ W	
Facility ID:	County: Des Moines		Civil Town/City/ or Village: Burlington		

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–7.5	FILL, boring location was cleared to 7.5' bgs by hydrovac, then back filled.	FILL									
S1	0		7.5–10	SILT, ash, (fill).	ML									
S2	16	13 8 6 11	10–15	SANDY SILT, very dark gray (2 5Y 3/1), sand is fine grained	ML					W				
S3	15	4 9 6 3								W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]	Firm: SCS Engineers, 2830 Dairy Drive Madison, WI 53718	Tel: 608-224-2830 Fax:

Boring Number MW-307

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
S4	18	1 3 5 5	16, 17	SANDY SILT, very dark gray (2.5Y 3/1), sand is fine grained. *(continued)*	ML					W				
S5	20	1 2 2 2	18, 19	LEAN CLAY, black (10YR 2/1).	CL					W				
S6	16	1 2 4 6	20, 21, 22	POORLY GRADED SAND, very dark gray (2.5Y 3/1), coarse grained.	SP					W				
S7	10	1 2 4 4	23, 24, 25							W				
S8	12	2 2 3 4	26							W				
			27	End of boring at 27 ft bgs.										

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SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-308

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/15/2015	12/16/2015	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-308	Feet	534.9 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,359 N, 2,300,306 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' "
Long ° ' "
Local Grid Location ☐ N ☐ E
Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	FILL, boring location was cleared to 5' bgs by hydrovac, then back filled.	FILL									
			5	SANDY SILT, olive brown (2.5Y 4/3).										
S1	14	22 12 13 15	6							W				
S2	18	2 2 4 8	8.5							W				
			10		MLS									
S3	18	1 2 2 50	11							W				
S4	14	3 15 50	13.5							W				
			15											

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

Firm SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number **MW-308**

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
				LEAN CLAY, black (2.5Y 2.5/1).	CL									
S5	12	6 4 2 4	16							W				
			17											
S6	12	5 6 5 10	18–19							W				
			20	SILT, very dark gray (7 5YR 3/1), trace sand.	ML									
S7	18	1 1 1 2	21							W				
			22											
			23	POORLY GRADED SAND, very dark gray (2.5Y 3/1), coarse grained.	SP									
S8	10	1 12 13 18	24							W				
			25											
S9	12	2 6 8 10	26							W				
			27											
S10		2 2 6 8	28–29							W				
				End of Boring at 29.5 ft bgs										

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SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name: IPL- Burlington Generating Station SCS#: 25215135.80		License/Permit/Monitoring Number	Boring Number: MW-309	
Boring Drilled By: Name of crew chief (first, last) and Firm: Kevin Collins, Direct Push Analytical		Date Drilling Started: 3/1/2016	Date Drilling Completed: 3/1/2016	Drilling Method: 4-1/2 hollow stem auger
Unique Well No.	DNR Well ID No.	Common Well Name: MW-309	Final Static Water Level: Feet	Surface Elevation: 534.1 Feet
Borehole Diameter: 8.5 in				

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,210 N, 2,300,022 E S/C/N
SW 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W

Lat ___ ° ___ ' ___ "
Long ___ ° ___ ' ___ "

Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID:
County: Des Moines
Civil Town/City/ or Village: Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled	FILL									
			10	LEAN CLAY, olive brown (2.5Y 4/3).	CL									
S1	14		11							W				
			12	Same as above except, gray (2.5Y 6/1)										
S2	34		14							W				
			15											

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]
Firm: SCS Engineers, 2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-309

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
				LEAN CLAY, olive brown (2.5Y 4/3). *(continued)*										
			16	Same as above except, very dark gray (2.5Y 3/1).	CL									
			17											
S3	34		18							W				
			19	POORLY GRADED SAND, coarse grained, very dark gray (10YR 3/1).										
			20											
			21		SP									
S4	31		22							W				
			23											
			24											
			25	End of Boring at 25 feet bgs.										

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SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-310

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	3/1/2016	3/1/2016	Direct Push 4-1/2/HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-310	Feet	532.2 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,610 N, 2,298,832 E S/C/N
NE 1/4 of SE 1/4 of Section 30, T 69 N, R 2 W
Lat ___ ° ___ ' ___ "
Long ___ ° ___ ' ___ "
Local Grid Location ☐ N ☐ S Feet; ☐ E ☐ W Feet

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	LEAN CLAY WITH SAND, dark olive brown (2.5Y 3/3).	CL									
S1	13		2							M				
S2	33		6							M				
			7	Same as above except, very dark gray (2.5Y 3/1).										
S3	22		10	Trace organics.						M				
			12	SILTY SAND, very dark grayish brown (2.5Y 3/2).	SM									
			13	POORLY GRADED SAND, coarse grained, very dark grayish brown (2.5Y 3/2).	SP									
S4	31		14							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]
Firm SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-310

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			16	POORLY GRADED SAND, coarse grained, very dark grayish brown (2.5Y 3/2). *(continued)*	SP									
			17											
S5	35		18							W				
			19											
			20	LEAN CLAY, dark gray (2.5Y 4/1).	CL									
			21	POORLY GRADED SAND, very dark grayish brown (2.5Y 3/2).	SP									
S6	NA		22							W				Sample stuck in discrete sampler. Refusal @24'.
			23	LEAN CLAY, dark gray (2.5Y 4/1), (weathered bedrock).	CL									
			24	End of Boring at 24 feet bgs.										

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SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐ Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-311

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	3/1/2016	3/1/2016	Direct Push 4-1/2/HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-311	Feet	532.7 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,439 N, 2,298,835 E S/C/N
NE 1/4 of SE 1/4 of Section 30, T 69 N, R 2 W
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	TOPSOIL.	TOPSOIL									
			0–4	LEAN CLAY, dark olive brown (2.5Y 3/3).	CL									
S1	14		2							M				
			4–8	POORLY GRADED SAND, yellowish brown (10YR 5/8), coarse grained.	SP									
S2	8		6							M				
			8–15	LEAN CLAY, very dark gray (2.5Y 3/1).	CL									
S3	6		10							M				Rock in shoe.
S4	25		14							M				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]
Firm: SCS Engineers, 2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-311

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
				LEAN CLAY, very dark gray (2.5Y 3/1). *(continued)*	CL									
S5	34		16–19	SILTY SAND, black (2.5Y 2.5/1).	SM					W				
			19–20	POORLY GRADED SAND, very dark grayish brown (2.5Y 3/2).	SP									
S6	40		20–23	SILTY SAND, very dark grayish brown (2.5Y 3/2).	SM					W				
			23–24	SILT, very dark grayish brown (2.5Y 3/2).	ML									
S7	45		24–28	LEAN CLAY, dark gray (2.5Y 4/1), laminated, organics.	CL					W				
			28–29	POORLY GRADED SAND, very dark grayish brown (2.5Y 3/2).	SP									
S8			29–32	LEAN CLAY, dark gray (2.5Y 4/1), laminated, organics. Same as above except, dark greenish gray (5GY 4/1), shells.	CL					W				
			32	End of Boring at 32 feet bgs.										

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SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IP&L - Burlington Generating Station SCS#: 25218220.00		MW313

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Roberts Environmental Drilling	5/21/2019	5/21/2019	4.25" HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW313	Feet	Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☐
State Plane N, E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2
Lat ° ' "
Long ° ' "
Local Grid Location ☐ N ☐ E
Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	Hydrovaced to 8'.										
			8	LEAN CLAY, (GLEY1 4/10Y), trace coarse sand.	CL									
	8	3 1 4 5	9							M				
	8	1 1 3 4	11							M				
			12	Trace organic material										
	8	1 1 2 2	13							M				
			15											

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
	SCS Engineers 3900 kilroy Airport Way Long Beach, CA 90806	Tel: Fax:

Boring Number MW313

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
	12	1 1 2 2		LEAN CLAY, (GLEY1 4/10Y), trace coarse sand. *(continued)*						M				
			16	Same as above but dark gray, (10YR 2/1).										
		1 1 2 2	17							M				
			18											
		1 1 2 2	19							M				
			20		CL									
	18	1 1 3 4	21							M				
			22											
	24	3 2 3 4	23							M				
			24	Small sand lenses.										
	18	1 1 2 8	25							M				
			26	POORLY GRADED SAND, coarse.										
	4		27							W				
			28											
	10	3 2 4 6	29		SP					W				
			30											
	0	1 3 8 7	31							W				
			32	End of Boring at 32 feet.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Remediation/Redevelopment ☐ Waste Management ☐ Other ☐

Facility/Project Name: IP&L - Burlington Generating Station SCS#: 25218220.00	License/Permit/Monitoring Number	Boring Number: MW312	
Boring Drilled By: Name of crew chief (first, last) and Firm: Jeff Roberts Environmental Drilling	Date Drilling Started: 5/20/2019	Date Drilling Completed: 5/20/2019	Drilling Method: 4.25" HSA
Unique Well No. / DNR Well ID No. / Common Well Name: MW312	Final Static Water Level: Feet	Surface Elevation: Feet	Borehole Diameter: 8.5 in
Local Grid Origin ☐ (estimated: ☐) or Boring Location ☐ State Plane N, E S/C/N; SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2	Lat ° ' " Long ° ' "	Local Grid Location ☐ N Feet ☐ S	☐ E Feet ☐ W
Facility ID	County: Des Moines	Civil Town/City/ or Village: Burlington	

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	Hydrovaced to 8'.										
	4	3 3 6 7	8	LEAN CLAY, teal/blue, (GLEY1 5/10 GY), trace coarse sand.	CL					M				
	18	3 4 5 7	10	same as above but dark green, (GLEY1 3/10 GY), with gravel.						M				
	10	1 2 5 8	12	trace organic material						M				
			14	same as above but dark green, (10YR 2/1).										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm SCS Engineers 3900 kilroy Airport Way Long Beach, CA 90806 Tel: Fax:

Boring Number MW312

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
	24	1 4 5 6		LEAN CLAY, teal/blue, (GLEY1 5/10 GY), trace coarse sand. *(continued)*						M				
			16											
			17							M				
			18		CL									
		2 3 3 4	19							M				
			20	POORLY GRADED SAND, fine to coarse, (2.5YR 3/2).										
	6	0 1 2 3	21							W				
			22											
	6	1 2 4 5	23		SP					W				
			24											
	4		25							W				
			26	End of Boring at 26 feet.										

Appendix C

Information on Molybdenum

Toxicological Profile for Molybdenum

Draft for Public Comment

April 2017

ATSDR

U.S. Department of Health and Human Services

Agency for Toxic Substances and Disease Registry

CS274127-A

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UPDATE STATEMENT

Toxicological profiles are revised and republished as necessary. For information regarding the update status of previously released profiles, contact ATSDR at:

Agency for Toxic Substances and Disease Registry
Division of Toxicology and Human Health Sciences
Environmental Toxicology Branch
1600 Clifton Road NE
Mailstop F-57
Atlanta, Georgia 30329-4027

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FOREWORD

This toxicological profile is prepared in accordance with guidelines developed by the Agency for Toxic Substances and Disease Registry (ATSDR) and the Environmental Protection Agency (EPA). The original guidelines were published in the *Federal Register* on April 17, 1987. Each profile will be revised and republished as necessary.

The ATSDR toxicological profile succinctly characterizes the toxicologic and adverse health effects information for these toxic substances described therein. Each peer-reviewed profile identifies and reviews the key literature that describes a substance's toxicologic properties. Other pertinent literature is also presented, but is described in less detail than the key studies. The profile is not intended to be an exhaustive document; however, more comprehensive sources of specialty information are referenced.

The focus of the profiles is on health and toxicologic information; therefore, each toxicological profile begins with a public health statement that describes, in nontechnical language, a substance's relevant toxicological properties. Following the public health statement is information concerning levels of significant human exposure and, where known, significant health effects. The adequacy of information to determine a substance's health effects is described in a health effects summary. Data needs that are of significance to the protection of public health are identified by ATSDR and EPA.

Each profile includes the following:

(A) The examination, summary, and interpretation of available toxicologic information and epidemiologic evaluations on a toxic substance to ascertain the levels of significant human exposure for the substance and the associated acute, subacute, and chronic health effects;

(B) A determination of whether adequate information on the health effects of each substance is available or in the process of development to determine levels of exposure that present a significant risk to human health of acute, subacute, and chronic health effects; and

(C) Where appropriate, identification of toxicologic testing needed to identify the types or levels of exposure that may present significant risk of adverse health effects in humans.

The principal audiences for the toxicological profiles are health professionals at the Federal, State, and local levels; interested private sector organizations and groups; and members of the public. We plan to revise these documents in response to public comments and as additional data become available. Therefore, we encourage comments that will make the toxicological profile series of the greatest use.

Electronic comments may be submitted via: www.regulations.gov.
Follow the on-line instructions for submitting comments.

Written comments may also be sent to:

Agency for Toxic Substances and Disease Registry
Division of Toxicology and Human Health Sciences
Environmental Toxicology Branch

Regular Mailing Address:
1600 Clifton Road, N.E.
Mail Stop F-57
Atlanta, Georgia 30329-4027

Physical Mailing Address:
4770 Buford Highway
Building 102, 1st floor, MS F-57
Chamblee, Georgia 30341

The toxicological profiles are developed under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA or Superfund). CERCLA section 104(i)(1) directs the Administrator of ATSDR to "…effectuate and implement the health related authorities" of the statute. This includes the preparation of toxicological profiles for hazardous substances most commonly found at facilities on the CERCLA National Priorities List and that pose the most significant potential threat to human health, as determined by ATSDR and the EPA. Section 104(i)(3) of CERCLA, as amended, directs the Administrator of ATSDR to prepare a toxicological profile for each substance on the list. In addition, ATSDR has the authority to prepare toxicological profiles for substances not found at sites on the National Priorities List, in an effort to "…establish and maintain inventory of literature, research, and studies on the health effects of toxic substances" under CERCLA Section 104(i)(1)(B), to respond to requests for consultation under section 104(i)(4), and as otherwise necessary to support the site-specific response actions conducted by ATSDR.

This profile reflects ATSDR's assessment of all relevant toxicologic testing and information that has been peer-reviewed. Staffs of the Centers for Disease Control and Prevention and other Federal scientists have also reviewed the profile. In addition, this profile has been peer-reviewed by a nongovernmental panel and is being made available for public review. Final responsibility for the contents and views expressed in this toxicological profile resides with ATSDR.

Patrick N. Breysse, Ph.D., CIH
Director, National Center for Environmental Health and
Agency for Toxic Substances and Disease Registry
Centers for Disease Control and Prevention

QUICK REFERENCE FOR HEALTH CARE PROVIDERS

Toxicological Profiles are a unique compilation of toxicological information on a given hazardous substance. Each profile reflects a comprehensive and extensive evaluation, summary, and interpretation of available toxicologic and epidemiologic information on a substance. Health care providers treating patients potentially exposed to hazardous substances may find the following information helpful for fast answers to often-asked questions.

Primary Chapters/Sections of Interest

Chapter 1: Public Health Statement: The Public Health Statement can be a useful tool for educating patients about possible exposure to a hazardous substance. It explains a substance's relevant toxicologic properties in a nontechnical, question-and-answer format, and it includes a review of the general health effects observed following exposure.

Chapter 2: Relevance to Public Health: The Relevance to Public Health Section evaluates, interprets, and assesses the significance of toxicity data to human health.

Chapter 3: Health Effects: Specific health effects of a given hazardous compound are reported by type of health effect (e.g.,death, systemic, immunologic, reproductive), by route of exposure, and by length of exposure (acute, intermediate, and chronic). In addition, both human and animal studies are reported in this section.
NOTE: Not all health effects reported in this section are necessarily observed in the clinical setting. Please refer to the Public Health Statement to identify general health effects observed following exposure.

Pediatrics: Four new sections have been added to each Toxicological Profile to address child health issues:
Chapter 1 **How Can (Chemical X) Affect Children?**
Chapter 1 **How Can Families Reduce the Risk of Exposure to (Chemical X)?**
Section 3.8 **Children's Susceptibility**
Section 6.6 **Exposures of Children**

Other Sections of Interest:
Section 3.9 **Biomarkers of Exposure and Effect**
Section 3.12 **Methods for Reducing Toxic Effects**

ATSDR Information Center
Phone: 1-800-CDC-INFO (800-232-4636) or 1-888-232-6348 (TTY)
Internet: http://www.atsdr.cdc.gov

The following additional materials are available online:

Case Studies in Environmental Medicine are self-instructional publications designed to increase primary health care providers' knowledge of a hazardous substance in the environment and to aid in the evaluation of potentially exposed patients (see https://www.atsdr.cdc.gov/csem/csem.html).

Managing Hazardous Materials Incidents is a three-volume set of recommendations for on-scene (prehospital) and hospital medical management of patients exposed during a hazardous materials incident (see https://www.atsdr.cdc.gov/MHMI/index.asp). Volumes I and II are planning guides to assist first responders and hospital emergency department personnel in planning for incidents that involve hazardous materials. Volume III—*Medical Management Guidelines for Acute Chemical Exposures*—is a guide for health care professionals treating patients exposed to hazardous materials.

Fact Sheets (ToxFAQs™) provide answers to frequently asked questions about toxic substances (see https://www.atsdr.cdc.gov/toxfaqs/Index.asp).

Other Agencies and Organizations

The National Center for Environmental Health (NCEH) focuses on preventing or controlling disease, injury, and disability related to the interactions between people and their environment outside the workplace. Contact: NCEH, Mailstop F-29, 4770 Buford Highway, NE, Atlanta, GA 30341-3724 • Phone: 770-488-7000 • FAX: 770-488-7015 • Web Page: https://www.cdc.gov/nceh/.

The National Institute for Occupational Safety and Health (NIOSH) conducts research on occupational diseases and injuries, responds to requests for assistance by investigating problems of health and safety in the workplace, recommends standards to the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA), and trains professionals in occupational safety and health. Contact: NIOSH, 395 E Street, S.W., Suite 9200, Patriots Plaza Building, Washington, DC 20201 • Phone: 202-245-0625 or 1-800-CDC-INFO (800-232-4636) • Web Page: https://www.cdc.gov/niosh/.

The National Institute of Environmental Health Sciences (NIEHS) is the principal federal agency for biomedical research on the effects of chemical, physical, and biologic environmental agents on human health and well-being. Contact: NIEHS, PO Box 12233, 104 T.W. Alexander Drive, Research Triangle Park, NC 27709 • Phone: 919-541-3212 • Web Page: https://www.niehs.nih.gov/.

Clinical Resources (Publicly Available Information)

The Association of Occupational and Environmental Clinics (AOEC) has developed a network of clinics in the United States to provide expertise in occupational and environmental issues. Contact: AOEC, 1010 Vermont Avenue, NW, #513, Washington, DC 20005 • Phone: 202-347-4976 • FAX: 202-347-4950 • e-mail: AOEC@AOEC.ORG • Web Page: http://www.aoec.org/.

The American College of Occupational and Environmental Medicine (ACOEM) is an association of physicians and other health care providers specializing in the field of occupational and environmental medicine. Contact: ACOEM, 25 Northwest Point Boulevard, Suite 700, Elk Grove Village, IL 60007-1030 • Phone: 847-818-1800 • FAX: 847-818-9266 • Web Page: http://www.acoem.org/.

The American College of Medical Toxicology (ACMT) is a nonprofit association of physicians with recognized expertise in medical toxicology. Contact: ACMT, 10645 North Tatum Boulevard, Suite 200-111, Phoenix AZ 85028 • Phone: 844-226-8333 • FAX: 844-226-8333 • Web Page: http://www.acmt.net.

The Pediatric Environmental Health Specialty Units (PEHSUs) is an interconnected system of specialists who respond to questions from public health professionals, clinicians, policy makers, and the public about the impact of environmental factors on the health of children and reproductive-aged adults. Contact information for regional centers can be found at http://pehsu.net/findhelp.html.

The American Association of Poison Control Centers (AAPCC) provide support on the prevention and treatment of poison exposures. Contact: AAPCC, 515 King Street, Suite 510, Alexandria VA 22314 • Phone: 701-894-1858 • Poison Help Line: 1-800-222-1222 • Web Page: http://www.aapcc.org/.

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THE PROFILE HAS UNDERGONE THE FOLLOWING ATSDR INTERNAL REVIEWS:

1. Health Effects Review. The Health Effects Review Committee examines the health effects chapter of each profile for consistency and accuracy in interpreting health effects and classifying end points.

2. Minimal Risk Level Review. The Minimal Risk Level Workgroup considers issues relevant to substance-specific Minimal Risk Levels (MRLs), reviews the health effects database of each profile, and makes recommendations for derivation of MRLs.

3. Data Needs Review. The Environmental Toxicology Branch reviews data needs sections to assure consistency across profiles and adherence to instructions in the Guidance.

4. Green Border Review. Green Border review assures the consistency with ATSDR policy.

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PEER REVIEW

A peer review panel was assembled for molybdenum. The panel consisted of the following members:

1. John Meeker, Sc.D., C.I.H., Professor, Environmental Health Sciences, Associate Dean for Research, School of Public Health, University of Michigan, Ann Arbor, Michigan;

2. Alexander V. Lyubimov, M.D., Ph.D., D.A.B.T., Toxicology Research Laboratory, Chicago, Illinois; and

3. Dagobert Heijerick, ARCHE consulting, Gent, Belgium.

These experts collectively have knowledge of molybdenum's physical and chemical properties, toxicokinetics, key health end points, mechanisms of action, human and animal exposure, and quantification of risk to humans. All reviewers were selected in conformity with the conditions for peer review specified in Section 104(I)(13) of the Comprehensive Environmental Response, Compensation, and Liability Act, as amended.

Scientists from the Agency for Toxic Substances and Disease Registry (ATSDR) have reviewed the peer reviewers' comments and determined which comments will be included in the profile. A listing of the peer reviewers' comments not incorporated in the profile, with a brief explanation of the rationale for their exclusion, exists as part of the administrative record for this compound.

The citation of the peer review panel should not be understood to imply its approval of the profile's final content. The responsibility for the content of this profile lies with the ATSDR.

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1. PUBLIC HEALTH STATEMENT FOR MOLYBDENUM

This Public Health Statement summarizes the Agency for Toxic Substances and Disease Registry's (ATSDR) findings on molybdenum, including chemical characteristics, exposure risks, possible health effects from exposure, and ways to limit exposure.

The U.S. Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are sites targeted for long-term federal clean-up activities. The EPA has found molybdenum in at least 86 of the 1,832 current or former NPL sites. The total number of NPL sites evaluated for molybdenum is not known. But the possibility remains that as more sites are evaluated, the sites where molybdenum is found may increase. This information is important because these future sites may be sources of exposure, and exposure to molybdenum may be harmful.

If you are exposed to molybdenum, many factors determine whether you'll be harmed. These include how much you are exposed to (dose), how long you are exposed (duration), how often you are exposed (frequency), and how you are exposed (route of exposure). You must also consider the other chemicals you are exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

WHAT IS MOLYBDENUM?

Molybdenum is a chemical element with the symbol Mo. Pure molybdenum exists as a dark-gray or black powder with a metallic luster or as a silvery-white mass. It does not occur naturally in the pure metallic form. It is principally found as oxide or sulfide compounds. Therefore, almost all exposure is to a molybdenum compound rather than the actual metal alone. Important naturally occurring molybdenum compounds are the minerals molybdenite, powellite, wulfenite, ferrimolybdite, and ilsemannite. Molybdenum has a very high melting point and it is used widely in industry to make steel alloys.

Molybdenum occurs naturally in all plants and animals. Low levels of molybdenum are required for good health in humans and animals.

WHAT HAPPENS TO MOLYBDENUM WHEN IT ENTERS THE ENVIRONMENT?

Molybdenum can enter the environment through releases from mining, milling, and smelting operations and coal-fired power plants. The primary source of molybdenum in air is from coal combustion.

Molybdenum released to the air will settle to the ground by gravity or in rain and snow. Molybdenum can also be directly released into surface water. When molybdenum is released into soil or water, it can become attached to the organic material and other components (such as clay, sand, etc.) in the top layers of the soil or in the water and may not move far from where it is released. The soil conditions, especially the acidity of the soil, will influence the binding of molybdenum to soil and sediment. Molybdenum does not break down in the environment.

HOW MIGHT I BE EXPOSED TO MOLYBDENUM?

Molybdenum is common in the environment. The primary way that you may be exposed to molybdenum is by eating food containing molybdenum. Grains, legumes, nuts, and dairy products have the highest levels of molybdenum. You may also be exposed to molybdenum in some nutritional supplements. You may be exposed to small amounts of molybdenum by breathing air, by drinking water, and by skin contact with soil and water. You may be exposed to higher levels of molybdenum in drinking water if you live near industries using molybdenum and the industries release molybdenum into the waterways.

HOW CAN MOLYBDENUM ENTER AND LEAVE MY BODY?

Molybdenum can enter your body when you breathe air, drink water, or eat food containing molybdenum. When you breathe air containing molybdenum, molybdenum particles can be deposited in your lungs. Some of these particles can be coughed up and swallowed. Particles deposited deeper in the lungs are likely to pass through the lining of the lungs and enter the bloodstream. Some of the molybdenum in the lungs may stay there for years. At least half of ingested molybdenum will enter the bloodstream. The amount of molybdenum absorbed depends on what other food and beverages are ingested. We do not have any information on whether molybdenum can enter the body through the skin. Molybdenum in the blood will be distributed throughout the body, with the highest amounts found in the liver and kidneys. Molybdenum leaves your body in urine and feces, mostly in urine. Generally, the amount of molybdenum in your body remains constant (the amount that enters your body equals the amount that leaves). More information on how molybdenum enters and leaves the body is presented in Chapter 3.

HOW CAN MOLYBDENUM AFFECT MY HEALTH?

Molybdenum is essential for good health. An intake of 45 micrograms of molybdenum per day (μg/day) is recommended for adults. On average, adults in the United States ingest 76–109 μg molybdenum per day.

Exposure to high levels of molybdenum can be harmful. Long-term exposure of rats and mice to molybdenum dust in the air can cause damage to the nasal cavity, epiglottis, and lungs. Studies in animals suggested that ingesting large amounts of molybdenum, at least 1,000 times higher than needed for health may damage the male and female reproductive system and might cause kidney and liver damage.

A study in mice provides some evidence that exposure to inhaled molybdenum can result in lung cancer. Molybdenum has not been classified as to carcinogenicity by the Department of Health and Human Services (HHS), the International Agency for Research on Cancer (IARC), or EPA.

More detailed information on the health effects of molybdenum in humans and animals can be found in Chapter 3.

HOW CAN MOLYBDENUM AFFECT CHILDREN?

This section discusses potential health effects of molybdenum exposure in humans from when they're first conceived to 18 years of age.

Children need small amounts of molybdenum to maintain good health. It is likely that the adverse health effects observed in adults exposed to higher than normal levels of molybdenum would also be observed in children. We do not know if children would be more susceptible to the toxicity of molybdenum than adults. We do not have enough information to determine whether molybdenum can cause birth defects or affect growth. Studies in humans and laboratory animals show that molybdenum is transferred from the mother to the fetus. Molybdenum has also been found in breast milk.

HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO MOLYBDENUM?

If your doctor finds that you have been exposed to significant amounts of molybdenum, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate. You may also contact the state or local health department with health concerns.

Molybdenum is part of the natural environment and you need some molybdenum in your diet to maintain good health. Families can be exposed to more molybdenum than is needed for health if they live near natural or industrial sources of molybdenum, such as mining sites. If you live in an area with high levels of molybdenum in drinking water, you may consider using bottled drinking water.

If you are exposed to molybdenum at work, you can wear protective equipment and can remove contaminated clothing before going home.

ARE THERE MEDICAL TESTS TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO MOLYBDENUM?

Molybdenum is normally found in all tissues of the body, as well as in blood, urine, and feces. High levels of molybdenum in the blood or urine can show that you have been exposed to higher than normal levels of molybdenum. Measuring blood molybdenum levels may only tell you if you have been very recently exposed to molybdenum. Urinary molybdenum levels are more likely to give information on long-term exposure to molybdenum. Tests to measure molybdenum levels in the body are not usually available at a doctor's office because they require special equipment. Although these tests can show that you have been exposed to higher than normal molybdenum levels, they cannot be used to predict how much molybdenum you have been exposed to or whether the exposure will result in an adverse health effect. More detailed information on the measurement of molybdenum is provided in Chapters 3 and 7.

WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but are not enforceable by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed as "not-to-exceed" levels; that is, levels of a toxic substance in air, water, soil, or food that do not exceed a critical value usually based on levels that affect animals; levels are then adjusted to help protect humans. Sometimes these not-to-exceed levels differ among federal organizations. Different organizations use different exposure times (e.g., an 8-hour workday or a 24-hour day), different animal studies, or emphasize some factors over others, depending on their mission.

Recommendations and regulations are also updated periodically as more information becomes available. For the most current information, check with the federal agency or organization that issued the regulation or recommendation.

The Institute of Medicine has made recommendation of the amount of molybdenum that is needed for good health; these values are called Recommended Dietary Allowances (RDAs). The RDAs are specific for different age groups:

- 17 μg/day for children aged 1–3 years
- 22 μg/day for children aged 4–8 years
- 34 μg/day for children aged 9–13 years
- 43 μg/day for teens aged 14–18 years
- 45 μg/day for adults
- 50 μg/day for pregnant and nursing women

EPA has determined that exposure to drinking water containing 0.08 milligrams per liter (mg/L) is not expected to cause effects that are harmful to children exposed for 1 or 10 days. Lifetime exposure to drinking water containing 0.04 mg/L is not likely to cause adverse health effects.

OSHA has set a limit of 5 milligrams per cubic meter (mg/m^3) for soluble molybdenum compounds and 15 mg/m^3 for insoluble molybdenum compounds and total dust in workroom air to protect workers during an 8-hour work shift (40-hour work week). NIOSH has not established a guideline for exposure to molybdenum to protect workers exposed up to 10 hours per workday. However, NIOSH has established a level of 5,000 mg/m^3 for insoluble molybdenum compounds and 1,000 mg/m^3 for soluble molybdenum compounds that it considers immediately dangerous and likely to cause death or immediate or delayed permanent adverse health effects, or to prevent escape.

Further information on regulations and guidelines pertaining to molybdenum is provided in Chapter 8.

WHERE CAN I GET MORE INFORMATION?

If you have any questions or concerns, please contact your community or state health or environmental quality department, or contact ATSDR at the address and phone number below. You may also contact your doctor if experiencing adverse health effects or for medical concerns or questions. ATSDR can also provide publicly available information regarding medical specialists with expertise and experience recognizing, evaluating, treating, and managing patients exposed to hazardous substances.

- Call the toll-free information and technical assistance number at 1-800-CDCINFO (1-800-232-4636) or

- Write to:
  Agency for Toxic Substances and Disease Registry
  Division of Toxicology and Human Health Sciences
  1600 Clifton Road NE
  Mailstop F-57
  Atlanta, GA 30329-4027

Toxicological profiles and other information are available on ATSDR's web site: http://www.atsdr.cdc.gov.

2. RELEVANCE TO PUBLIC HEALTH

2.1 BACKGROUND AND ENVIRONMENTAL EXPOSURES TO MOLYBDENUM IN THE UNITED STATES

Molybdenum (Mo) is a naturally occurring trace element that can be found extensively in nature. Molybdenum is a metal that exists as a dark-gray or black powder with a metallic luster or as a silvery-white mass. It does not occur naturally in the pure metallic form, but principally as oxide or sulfide compounds. Therefore, almost all exposure is to a molybdenum compound rather than the actual metal. Important naturally occurring molybdenum compounds are the minerals molybdenite, powellite, wulfenite, ferrimolybdite, and ilsemannite.

Biologically, molybdenum plays an important role as a micronutrient in plants and animals, including humans. It is used widely in industry for metallurgical applications; some of these applications include high temperature furnaces, as a support wire for tungsten filaments in incandescent light bulbs, and as a component of steel used in solar panels and wind turbines.

Molybdenum is more abundant in areas of natural mineral deposits and can be found in all environmental media. Higher concentrations in air, water, and soil can be found near industrial operations due to contamination. Molybdenum concentrations in ambient air have been reported to range from below detection limits to 0.03 mg/m^3. Concentrations of molybdenum in ambient air of urban areas, 0.01–0.03 $\mu g/m^3$, are higher than those found in rural areas, 0.001–0.0032 $\mu g/m^3$. It has been reported that concentrations of molybdenum in surface waters are generally <1.0 μg/L and drinking water and groundwaters contain about 1.0 μg/L. Near industrial sources, surface water molybdenum concentrations can reach 200–400 μg/L and groundwater concentrations can reach 25,000 μg/L. Concentrations as high as 1,400 μg/L have been detected in drinking waters in areas impacted by mining and milling operations, far exceeding the U.S. Geological Survey (USGS) health-based screening level of 40 μg/L. Globally, most soils contain molybdenum at concentrations between 0.6 and 3.5 ppm, although total concentrations in soils can vary widely depending on geological composition or industrial contamination. The average concentration of soils is generally 1–2 ppm. In the United States, it has been reported that the median concentration of molybdenum in soils is 1.2–1.3 ppm, with a range of 0.1–40 ppm.

The exposure to molybdenum to the general population is almost entirely through food. Foods derived from above-ground plants, such as legumes, leafy vegetables, and cauliflower, generally have a relatively higher concentration of molybdenum in comparison to food from tubers or animals. Beans, cereal grains, leafy vegetables, legumes, liver, and milk are reported as the richest sources of molybdenum in the average diet. Drinking water coming from sources close to areas with high molybdenum contamination from industrial effluents may contain a higher concentration of molybdenum. The primary source of dietary molybdenum intake among children in the United States is milk. Exposure to molybdenum in an industrial setting such as mining can be significant.

2.2 SUMMARY OF HEALTH EFFECTS

Molybdenum, as a component of pterin-based cofactor, is an essential element. Historically, three molybdenum cofactor-containing enzymes have been identified: sulfite oxidase, xanthine oxidase, and aldehyde oxidase. These enzymes are involved in the degradation of sulfur-containing amino acids and sulfatides, purine degradation pathway catalyzing the oxidation of hypoxanthine to xanthine and of xanthine to uric acid, and oxidation of aromatic and nonaromatic heterocycles and aldehydes to carboxylic acids. Within the last 10 years, a fourth enzyme, mitochondrial amidoxime reducing component (mARC), has been identified in mammals. Clear signs of molybdenum deficiency have not been found in healthy humans. However, a deficiency in molybdenum cofactor has been observed in individuals with a severe metabolic defect. The lack of molybdenum cofactor and subsequent deficiencies in molybdoenzymes is manifested in central nervous system effects. The effects that typically occur shortly after birth include intractable seizures and feeding difficulties; the patients develop severe psychomotor retardation due to progressive cerebral atrophy and ventricular dilatation. The nutritional requirements for molybdenum are based on maintaining molybdenum balance; the Institute of Medicine has established the following age-specific RDAs:

- 17 μg/day for 1–3 year olds,
- 22 μg/day for 4–8 year olds,
- 34 μg/day for 9–13 year olds,
- 43 μg/day for 14–18 year olds,
- 45 μg/day (0.64 μg/kg/day) for adults, and
- 50 μg/day in pregnant and lactating women.

A small number of studies have investigated the toxicity of molybdenum following inhalation exposure. Decreases in lung function, dyspnea, and cough were reported in workers exposed to fine or ultrafine molybdenum trioxide dust. Another study of workers at a molybdenite roasting facility exposed to molybdenum trioxide and other oxides did not have alterations in lung function. However, this study did find an increase in serum uric acid levels. In studies of rats and mice exposed to molybdenum trioxide for 2 years, hyaline degeneration of the nasal epithelium, squamous metaplasia of the epiglottis, and chronic inflammation (rats only) were observed. However, no effects were observed following a 13-week exposure to similar concentrations. No other alterations were observed in the intermediate- or chronic-duration studies.

The oral toxicity of molybdenum has been well-established in ruminants, particularly cows and sheep. The toxicity is likely due to an interaction between molybdenum and sulfate in the rumen, resulting in the formation of thiomolybdates. In the absence of adequate copper in the rumen, the thiomolybdate is absorbed through the rumen or small intestine and can bind to copper-containing compounds such as ceruloplasmin and cytochrome oxidase, resulting in symptoms resembling copper deficiency (a condition often referred to as molybdenosis). The observed effects can include decreases in weight gain, alterations in hair/wool texture and pigmentation, delayed puberty, and reduced conception rates. Molybdenum also interacts with copper in monogastric animals; however, the mode of interaction differs between the species. Exposure to molybdenum results in decreases in blood and liver copper levels in ruminants, which is in contrast to the higher relative levels of liver and kidney copper in rats fed a copper-deficient diet, as compared to those fed a copper-adequate diet. Exposure to a molybdenum excess and copper-deficient diet also resulted in higher relative levels of liver molybdenum and lower relative levels of kidney molybdenum. Exposure of rats to thiomolybdate compounds can result in effects that mimic copper deficiency. These data suggest that the findings in ruminants do not appear to be relevant to humans or monogastric animals. Additionally, studies in which laboratory animals were fed a copper-deficient diet may not be relevant to evaluating the risk of molybdenum toxicity to the general population with adequate copper intake. A human study showed that a 24-day exposure to high molybdenum levels in the diet (1,490 μg/day, approximately 21 mg/kg/day) did not result in any significant alterations in copper metabolism. In the United States, the average copper intake is 1.0–1.6 mg/day and the copper recommended dietary allowance is 0.9 mg/day.

A small number of studies have evaluated the toxicity of molybdenum in humans following oral exposure. An increased occurrence of gout and increased blood uric acid levels were observed in residents living in an area of high molybdenum levels in the soil; no alterations in urinary uric acid levels were found in a 10-day experimental study in men. Several studies have used the National Health and Nutrition Examination Survey (NHANES) dataset to evaluate potential associations between urinary molybdenum levels and several diseases; statistically significant associations were found for the occurrence of high blood pressure, self-reported liver conditions, and decreased triiodothyronine or thyroxine. Although the studies did not specifically evaluate copper intake, it is likely to be adequate based on a NAS finding that copper intake in the United States is greater than or equal to the dietary requirement. Other population studies have found significant associations between blood molybdenum levels and sperm concentration and morphology or testosterone levels and between urinary molybdenum levels and the psychomotor index in infants. Although the observational epidemiology studies have found statistically significant associations, they do not establish causality and it is possible that the effects are not due to molybdenum exposure.

A number of studies have examined the oral toxicity in laboratory animals. Studies in which the basal diet provided an adequate amount of copper have identified a number of end points including hepatic effects, renal effects, reproductive effects, and possibly developmental effects. Based on the available animal data, the reproductive effects appear to be the most sensitive targets. Consistent with the findings in an epidemiology study, decreases in sperm motility and concentration and increases in sperm morphological changes have been observed in rats exposed to ≥4.4 mg molybdenum/kg/day as ammonium tetrathiomolybdate or sodium molybdate. Degeneration of the seminiferous tubules was also observed at similar molybdenum doses. Effects have also been observed in the female reproductive system (oocyte morphological alterations, abnormal rate of ovulation, and irregularities in the estrous cycle) at ≥1.5 mg molybdenum/kg/day in rats. Mixed results have been observed in animal developmental toxicity studies. Decreases in the number of live fetuses and fetal growth were observed in rats administered 14 mg molybdenum/kg as sodium molybdate; however, no developmental effects were observed in rats at 4.4 or 38 mg/kg/day as ammonium tetrathiomolybdate or sodium molybdate, respectively. Several studies have reported renal effects in rats exposed to ≥60 mg/kg/day. The effects included hyperplasia of the renal proximal tubules, degeneration, increases in total lipid levels in the kidney, and diuresis and creatinuria. The liver effects, which consisted of decreases in glycogen content, increases in aminotransferase activities, and increases in lipid content, have been observed at higher doses (≥300 mg/kg/day) that are often associated with body weight losses. No hepatic effects have been observed at lower (≤60 mg/kg/day) doses.

2.3 MINIMAL RISK LEVELS (MRLs)

As summarized in Table 2-1, an inhalation MRL has been derived for chronic-duration exposure to molybdenum and oral MRLs have been derived for acute- and intermediate-duration exposure to molybdenum. The chronic-duration inhalation MRL is based on squamous metaplasia of the epiglottis in female mice exposed to molybdenum trioxide 6 hours/day, 5 days/week for 2 years (NTP 1997). Acute-and intermediate-duration inhalation MRLs were not derived because the available studies did not identify adverse effects in rats or mice exposed for 14 days or 13 weeks (NTP 1997); the acute-duration study did identify a no-observed-adverse-effect level (NOAEL) and lowest-observed-adverse-effect levels (LOAELs) for decreases in body weight gain, but this was not considered a primary effect. The acute- and intermediate-duration oral MRLs for molybdenum were based on reproductive effects in female mice and rats, respectively. The data were considered inadequate for derivation of a chronic-duration oral MRL for molybdenum. Refer to Section 3.6.2 and Appendix A for detailed information regarding MRL derivation for molybdenum.

Table 2-1. Minimal Risk Levels (MRLs) for Molybdenum[a]

Exposure duration	MRL	Critical effect	Point of departure	Uncertainty factor	Reference
Inhalation exposure					
Acute	Insufficient data for derivation of an MRL				
Intermediate	Insufficient data for derivation of an MRL				
Chronic	0.0004 mg Mo/m^3	Squamous metaplasia in female mice exposed to ≥6.7 mg Mo/m^3	$BMCL_{HEC}$ of 0.012 mg Mo/m^3	30	NTP 1997
Oral exposure					
Acute	0.05 Mg Mo/kg/day	Increase rate of abnormal MII oocytes in mice	NOAEL of 5.3 mg Mo/kg/day	100	Zhang et al. 2013
Intermediate	0.008 mg Mo/kg/day	Increased estrous cycle length in rats	NOAEL of 0.76 mg Mo/kg/day	100	Fungwe et al. 1990
Chronic	Insufficient data for derivation of an MRL				

[a]The respective exposure durations for acute, intermediate, and chronic MRLs are ≤14 days, 15–364 days, and ≥1 year.

BMCL = benchmark concentration lower confidence limit; HEC = human equivalent concentration; NOAEL = no-observed-adverse-effect level

3. HEALTH EFFECTS

3.1 INTRODUCTION

The primary purpose of this chapter is to provide public health officials, physicians, toxicologists, and other interested individuals and groups with an overall perspective on the toxicology of molybdenum. It contains descriptions and evaluations of toxicological studies and epidemiological investigations and provides conclusions, where possible, on the relevance of toxicity and toxicokinetic data to public health.

A glossary and list of acronyms, abbreviations, and symbols can be found at the end of this profile.

3.2 DISCUSSION OF HEALTH EFFECTS BY ROUTE OF EXPOSURE

To help public health professionals and others address the needs of persons living or working near hazardous waste sites, the information in this section is organized first by route of exposure (inhalation, oral, and dermal) and then by health effect (e.g., death, systemic, immunological, neurological, reproductive, developmental, and carcinogenic effects). These data are discussed in terms of three exposure periods: acute (14 days or less), intermediate (15–364 days), and chronic (365 days or more).

Levels of significant exposure for each route and duration are presented in tables and illustrated in figures. The points in the figures showing no-observed-adverse-effect levels (NOAELs) or lowest-observed-adverse-effect levels (LOAELs) reflect the actual doses (levels of exposure) used in the studies. LOAELs have been classified into "less serious" or "serious" effects. "Serious" effects are those that evoke failure in a biological system and can lead to morbidity or mortality (e.g., acute respiratory distress or death). "Less serious" effects are those that are not expected to cause significant dysfunction or death, or those whose significance to the organism is not entirely clear. ATSDR acknowledges that a considerable amount of judgment may be required in establishing whether an end point should be classified as a NOAEL, "less serious" LOAEL, or "serious" LOAEL, and that in some cases, there will be insufficient data to decide whether the effect is indicative of significant dysfunction. However, the Agency has established guidelines and policies that are used to classify these end points. ATSDR believes that there is sufficient merit in this approach to warrant an attempt at distinguishing between "less serious" and "serious" effects. The distinction between "less serious" effects and "serious" effects is considered to be important because it helps the users of the profiles to identify levels of exposure at which major health effects start to appear. LOAELs or NOAELs should also help in determining whether or not the effects vary with dose and/or duration, and place into perspective the possible significance of these effects to human health.

The significance of the exposure levels shown in the Levels of Significant Exposure (LSE) tables and figures may differ depending on the user's perspective. Public health officials and others concerned with appropriate actions to take at hazardous waste sites may want information on levels of exposure associated with more subtle effects in humans or animals (LOAELs) or exposure levels below which no adverse effects (NOAELs) have been observed. Estimates of levels posing minimal risk to humans (Minimal Risk Levels or MRLs) may be of interest to health professionals and citizens alike.

A User's Guide has been provided at the end of this profile (see Appendix C). This guide should aid in the interpretation of the tables and figures for Levels of Significant Exposure and the MRLs.

3.2.1 Inhalation Exposure

The highest NOAEL values and all LOAEL values from each reliable study for each end point in each species and duration category are recorded in Table 3-1 and plotted in Figure 3-1.

3.2.1.1 Death

No deaths were reported in rats or mice exposed to ≤200 mg molybdenum/m^3 for 14 days (NTP 1997) or ≤67 mg molybdenum/m^3 for 90 days or 2 years (NTP 1997).

3.2.1.2 Systemic Effects

No information was located regarding cardiovascular, gastrointestinal, hematological, muscular/skeletal, hepatic, renal, endocrine, dermal, ocular, or body weight effects in humans following inhalation exposure to molybdenum. No information was located regarding dermal or ocular effects in animals following inhalation exposure to molybdenum.

The highest NOAEL values and all LOAEL values from each reliable study for systemic effects in each species and duration category are recorded in Table 3-1 and plotted in Figure 3-1.

Respiratory Effects. Limited data are available on the toxicity of molybdenum to the respiratory tract of humans. A study of workers exposed to molybdenum trioxide and other oxides at a molybdenite

Table 3-1. Levels of Significant Exposure to Molybdenum – Inhalation

Figure key[a]	Species (strain) No./group	Exposure duration/ concentrations	Parameters monitored	System	NOAEL (mg/m^3)	Less serious LOAEL (mg/m^3)	Serious LOAEL (mg/m^3)	Results	Reference/comments
ACUTE EXPOSURE									
Systemic									
1	Rat 5M, 5F (F344/N)	6 hours/day; 5 days/week; 14 days 0, 2, 6.7, 20, 67, 200 mg Mo/m^3	CS, BW, HP	Resp	200			No histological alterations were observed in the nasal cavity. Decreased body weight gain in males exposed to 67 mg/m^3 (10%) and females exposed to 200 mg/m^3 (13%); weight loss was observed in males exposed to 200 mg/m^3.	NTP 1997 (molybdenum trioxide)
				Bd Wt		67	200		
2	Mouse 5M, 5F (B6C3F1)	6 hours/day; 5 days/week; 14 days 0, 2, 6.7, 20, 67, 200 mg Mo/m^3	CS, BW, HP	Resp	200			No histological alterations were observed in the nasal cavity. Body weight loss in males and decrease in body weight gain in females.	NTP 1997 (molybdenum trioxide)
				Bd Wt			200		
INTERMEDIATE EXPOSURE									
Systemic									
3	Rat 10M, 10F (F344/N)	6.5 hours/day; 5 days/week; 13 weeks 0, 0.67, 2, 6.7, 20, 67mg Mo/m^3	CS, BW,OW, HP	Resp	67			No alterations in organ weights, hematology or clinical chemistry parameters, or histological alterations were found.	NTP 1997 (molybdenum trioxide)
				Cardio	67				
				Gastro	67				
				Hemato	67				
				Musc/skel	67				
				Hepatic	67				
				Renal	67				
				Endocr	67				
				Bd Wt	67				
4	Mouse 10M, 10F (B6C3F1)	6.5 hours/day; 5 days/week; 13 weeks 0, 0.67, 2, 6.7, 20, 67mg Mo/m^3	CS, BW,OW, HP	Resp	67			No alterations in organ weights, hematology or clinical chemistry parameters, or histological alterations were found.	NTP 1997 (molybdenum trioxide)
				Cardio	67				
				Gastro	67				
				Hemato	67				
				Musc/skel	67				
				Hepatic	67				
				Renal	67				
				Endocr	67				
				Bd Wt	67				

Table 3-1. Levels of Significant Exposure to Molybdenum – Inhalation

Figure key[a]	Species (strain) No./group	Exposure duration/ concentrations	Parameters monitored	System	NOAEL (mg/m^3)	Less serious LOAEL (mg/m^3)	Serious LOAEL (mg/m^3)	Results	Reference/comments
Reproductive									
5	Rat 10M, 10F (F344/N)	6.5 hours/day; 5 days/week; 13 weeks 0, 0.67, 2, 6.7, 20, 67mg Mo/m^3	CS, BW,OW, HP		67			No significant alterations in sperm counts or motility were found	NTP 1997 (molybdenum trioxide)
6	Mouse 10M, 10F (B6C3F1)	6.5 hours/day; 5 days/week; 13 weeks 0, 0.67, 2, 6.7, 20, 67mg Mo/m^3	CS, BW,OW, HP		67			No significant alterations in sperm counts or motility were found	NTP 1997 (molybdenum trioxide)
CHRONIC EXPOSURE									
Systemic									
7	Rat 50M, 50F (F344/N)	6 hours/day; 5 days/week; 105 weeks 0, 6.7, 20, 67mg Mo/m^3	CS, BW, HP	Resp		6.7		Concentration-related increasing incidence of hyaline degeneration of nasal respiratory and olfactory epithelium (females only), squamous metaplasia of the epiglottis, and chronic lung inflammation (only significant at 20 and 67 mg/m^3 concentrations)	NTP 1997 (molybdenum trioxide)
				Cardio	67				
				Gastro	67				
				Musc/skel	67				
				Hepatic	67				
				Renal	67				
				Endocr	67				
				Bd Wt	67				
8	Mouse 50M, 50F (B6C3F1)	6 hours/day; 5 days/week; 105 weeks 0, 6.7, 20, 67mg Mo/m^3	CS, BW, HP	Resp		6.7		Concentration-related increasing incidence of squamous metaplasia of the epiglottis, histiocytic cellular infiltration in the lungs, and alveolar epithelial metaplasia were observed at 6.7, 20, and 67 mg/m^3. Other respiratory effects were nasal supprative inflammation in males at 20 or 67 mg/m^3 and hyaline degeneration of nasal respiratory and olfactory epithelium (females only) at 67 mg/m^3.	NTP 1997 (molybdenum trioxide)
				Cardio	67				
				Gastro	67				
				Musc/skel	67				
				Hepatic	67				
				Renal	67				
				Endocr	67				
				Bd Wt	67				

Table 3-1. Levels of Significant Exposure to Molybdenum – Inhalation

Figure key[a]	Species (strain) No./group	Exposure duration/ concentrations	Parameters monitored	System	NOAEL (mg/m^3)	Less serious LOAEL (mg/m^3)	Serious LOAEL (mg/m^3)	Results	Reference/comments
Cancer									
9	Mouse 50M, 50F (B6C3F1)	6 hours/day; 5 days/week; 105 weeks 0, 6.7, 20, 67mg Mo/m^3	CS, BW, HP				6.7	Increased incidences of alveolar/bronchiolar carcinoma in males at ≥6.7 mg/m^3; increased incidence of alveolar/bronchiolar adenoma in females at ≥20 mg/m^3. An increase in alveolar/bronchiolar adenoma or carcinoma were also observed in male mice exposed to 6.7 or 20 mg/m^3.	NTP 1997 (molybdenum trioxide)

[a]The number corresponds to entries in Figure 3-1.

BC = biochemistry; BW = body weight; Cardio = cardiovascular; CI = confidence interval; CS = clinical signs; d = day(s); Endocr = endocrine; F = female(s); FI = food intake; Gastro = gastrointestinal; GC = gas chromatography; GN = gross necropsy; HE = hematology; Hemato = hematology; HP = histopathology; hr = hour(s); LC_{50} = lethal concentration, 50% kill; LE = lethality; M = male(s); min = minute(s); MRL = Minimal Risk Level; NS = not specified; OP = ophthalmology; OW = organ weight; RD_{50} = concentration resulting in a 50% reduction in respiratory rate; Resp = respiratory; sec = second(s); UR = urinalysis; WI = water intake; wk = week(s)

Figure 3-1. Levels of Significant Exposure to Molybdenum - Inhalation
Acute (≤ 14 days)

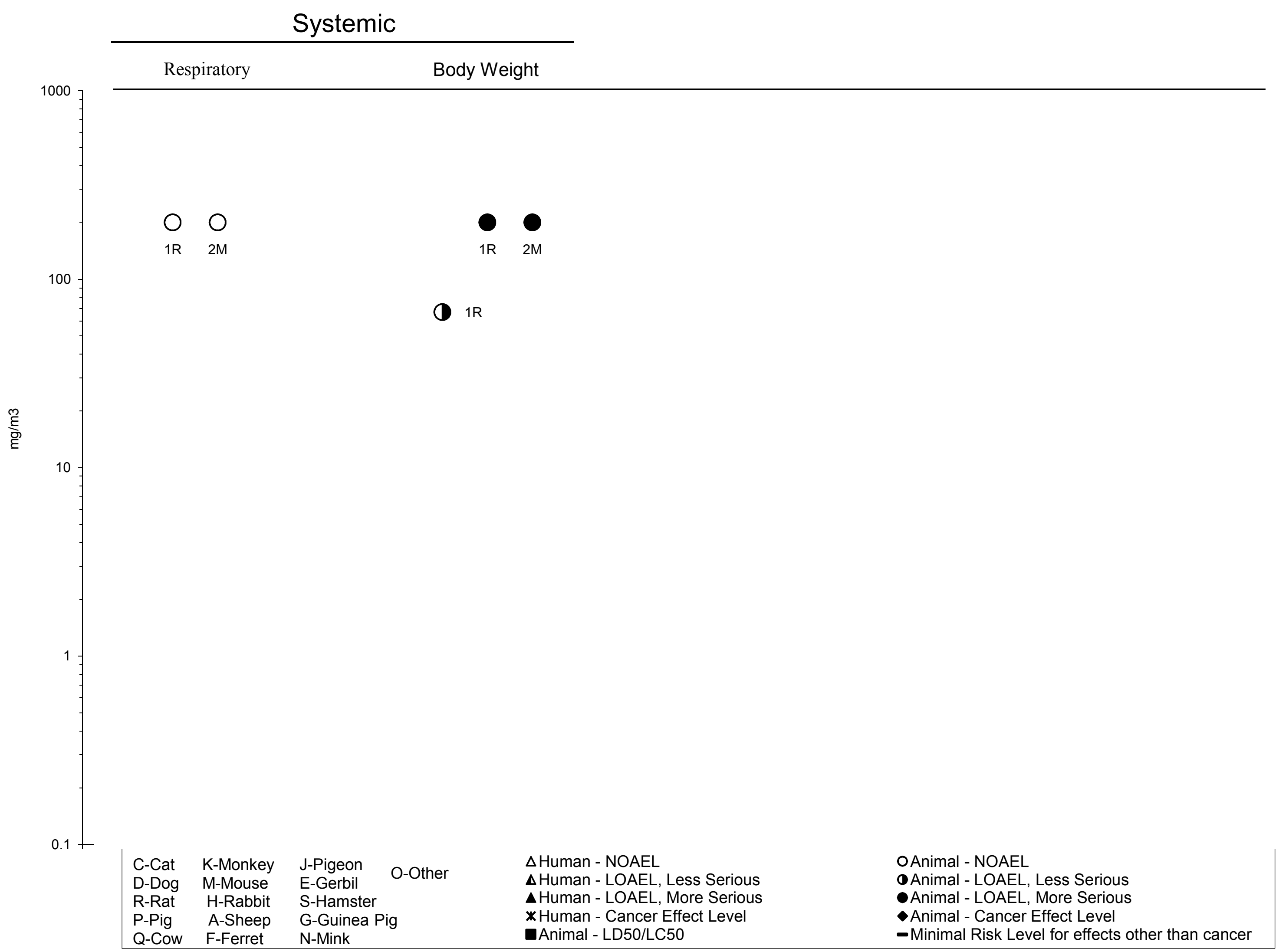


Figure 3-1. Levels of Significant Exposure to Molybdenum - Inhalation *(Continued)*
Intermediate (15-364 days)

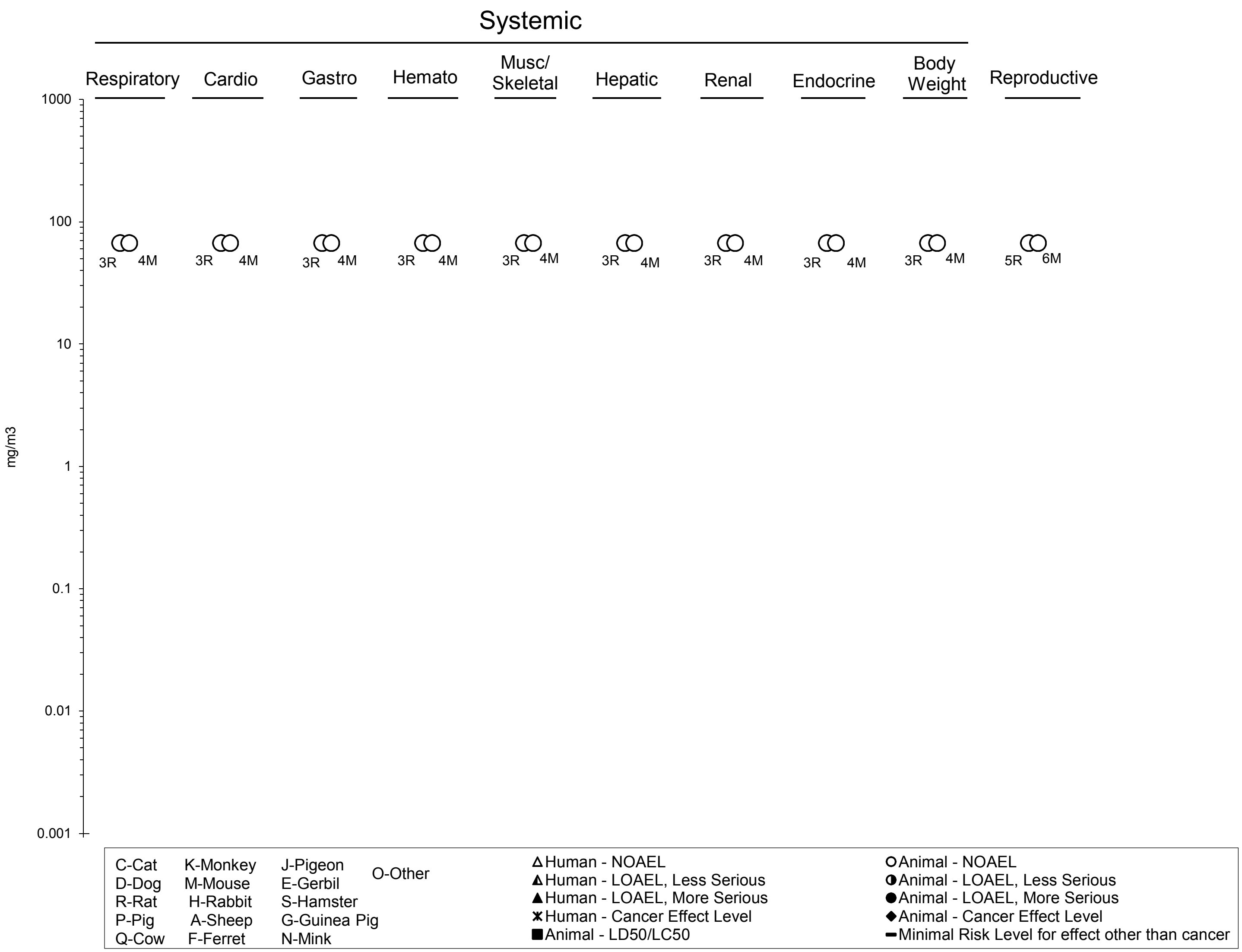
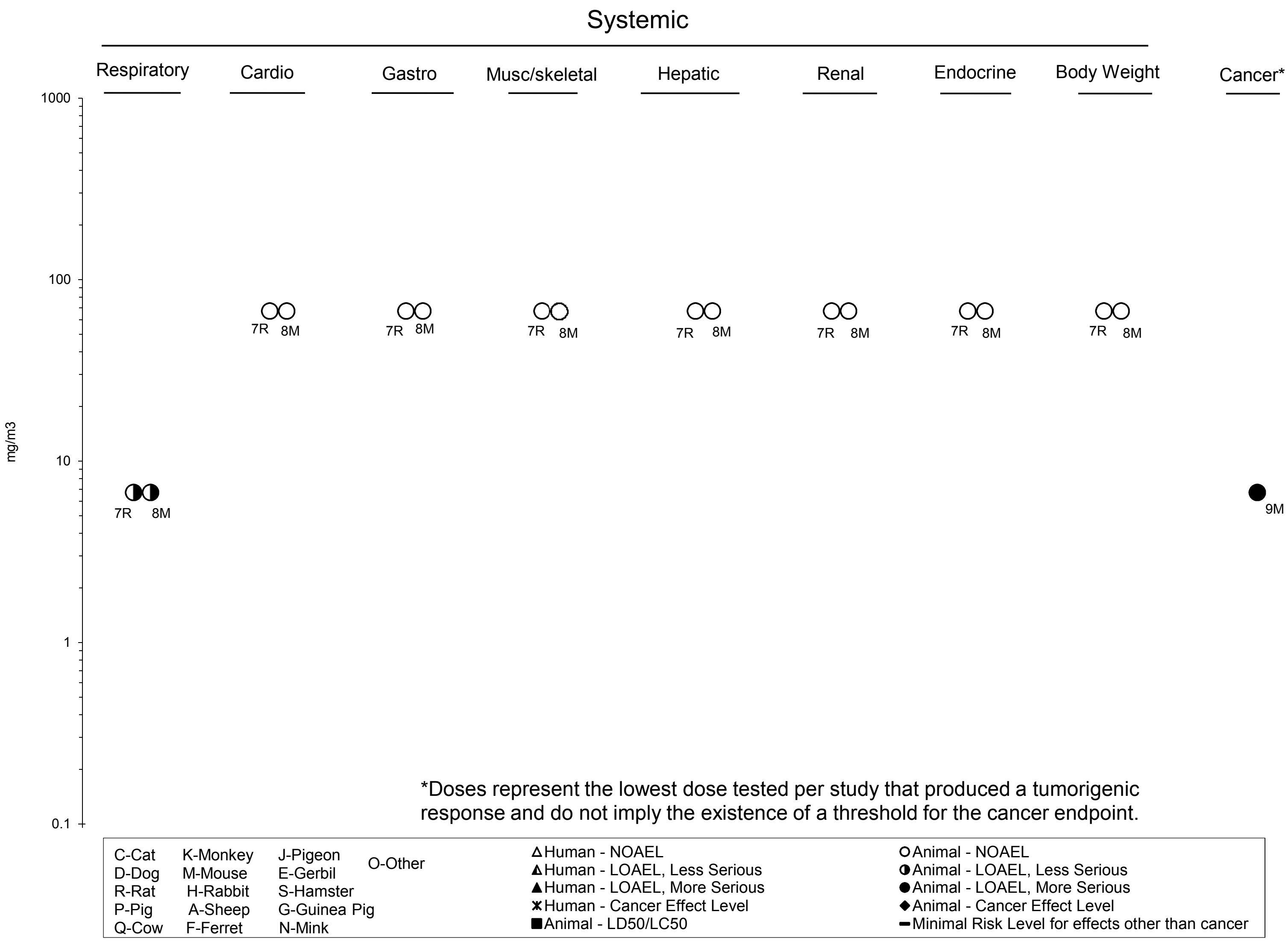


Figure 3-1. Levels of Significant Exposure to Molybdenum - Inhalation *(Continued)*
Chronic (≥365 days)



roasting plant reported normal lung function test results in 20/25 workers (Walravens et al. 1979). Some alterations in lung function (forced expiratory volume in 1 second, FEV_1) was observed in the remaining five workers; the decrease in FEV_1 was characterized as mild in three of the workers and "more marked" in two workers, which may be indicative of mild obstructive lung disease. The study did not provide lung function data for a reference group. The estimated 8-hour time-weighted average (TWA) molybdenum concentration in total dust was 9.46 mg molybdenum/m^3; the molybdenum content of the respirable dust ranged from 1.02 to 4.49 mg molybdenum/m^3. Another study of workers exposed to fine and ultrafine molybdenum trioxide dust reported dyspnea and cough in symptomatic workers (Ott et al. 2004). Radiographic abnormalities were noted in the lungs of most of the symptomatic workers and in half of the asymptomatic workers, although none of the radiographs showed evidence of interstitial lung disease. Significant alterations in lung function (increased predicted FEV_1 and forced vital capacity) were also observed in the workers, as compared to a control group. In symptomatic workers, alterations in bronchioalveolar lavage cytology suggestive of subclinical alveolitis were noted. This study (Ott et al. 2004) has several limitations including the lack of monitoring data, minimal information on the control group, which does not appear to be comprised of workers at this facility, and differences in the mean and ranges of ages of the different groups (40.0 years [range of 24–58 years], 30.5 years [22–45 years], and 30.0 years [14–72 years] in the symptomatic workers, asymptomatic workers, and controls, respectively), which were not adjusted for in the statistical analyses.

The database on the respiratory toxicity of molybdenum in laboratory animals is comprised of acute-, intermediate-, and chronic-duration studies conducted by the National Toxicology Program (NTP 1997). No histological alterations were observed in the nasal cavity of rats and mice exposed to 200 mg molybdenum/m^3 as molybdenum trioxide for 14 days (NTP 1997); no other regions of the respiratory tract were examined. Similarly, no histological alterations were observed in the respiratory tract of rats or mice exposed to ≤67 mg molybdenum/m^3 as molybdenum trioxide for 13 weeks (NTP 1997). In contrast, chronic exposure has resulted in lesions in the nose, larynx, and lungs in rats and mice exposed to molybdenum trioxide for 2 years (NTP 1997). In the nose, hyaline degeneration of the respiratory and olfactory epitheliums were observed in rats exposed to ≥6.7 mg molybdenum/m^3 and in mice exposed to 67 mg molybdenum/m^3; other nasal lesions observed in mice included suppurative inflammation at ≥20 mg molybdenum/m^3 and olfactory epithelial atrophy at 67 mg molybdenum/m^3. Squamous metaplasia of the epiglottis was observed in rats and mice exposed to ≥6.7 mg molybdenum/m^3. In the lungs, chronic inflammation was observed in rats exposed to ≥20 mg molybdenum/m^3 and alveolar epithelial metaplasia and histiocytic cellular infiltration were observed at ≥6.7 mg molybdenum/m^3.

Cardiovascular Effects. No histological alterations were observed in the hearts of rats or mice exposed to molybdenum trioxide concentrations as high as 67 mg molybdenum/m^3 for 13 weeks or 2 years (NTP 1997).

Gastrointestinal Effects. Intermediate- or chronic-duration exposure to ≤67 mg molybdenum/m^3 as molybdenum trioxide did not result in histological alterations in the gastrointestinal tract (NTP 1997).

Hematological Effects. No significant alterations in hematological parameters were observed in rats or mice following exposure to molybdenum trioxide concentrations as high as 67 mg molybdenum/m^3 for 13 weeks (NTP 1997).

Musculoskeletal Effects. No histological alterations were observed in the bone of rats or mice exposed to 6.7–67 mg molybdenum/m^3 as molybdenum trioxide for 13 weeks or 2 years (NTP 1997). Chronic molybdenum exposure also did not affect femoral bone density or curvature in groups of 10 rats exposed to concentrations as high as 67 mg molybdenum/m^3 (NTP 1997).

Hepatic Effects. No significant alterations in serum clinical chemistry parameters or liver weights were observed in rats or mice exposed to molybdenum trioxide concentrations as high as 67 mg molybdenum/m^3 for 13 weeks (NTP 1997). No significant alterations in the incidence of hepatic lesions were observed following 13 weeks or 2 years of exposure (NTP 1997).

Renal Effects. Intermediate- or chronic-duration inhalation exposure to molybdenum trioxide (highest concentration tested was 67 mg molybdenum/m^3) did not result in histological alterations in the kidney of rats or mice (NTP 1997).

Endocrine Effects. Based on histopathology findings, the adrenal, pituitary, pancreas, parathyroid, and thyroid glands were not affected by exposure of rats and mice to ≤67 mg molybdenum/m^3 as molybdenum trioxide for 13 weeks or 2 years (NTP 1997).

Body Weight Effects. Decreases in body weight gain and weight loss were observed in rats and mice exposed to molybdenum trioxide for 14 days (NTP 1997). Terminal body weights were 10% lower in male rats exposed to 67 mg molybdenum/m^3 than in the controls, and weight loss was observed in male rats and mice exposed to 200 mg molybdenum/m^3. In female rats and mice exposed to 200 mg molybdenum/m^3, the terminal body weights were 13 and 10%, respectively, lower than the control groups. No significant alterations in body weight gain were observed in rats or mice exposed to molybdenum trioxide concentrations as high as 67 mg molybdenum/m^3 for 13 weeks or 2 years (NTP 1997).

Other Systemic Effects. Slight, but significant increases in serum uric acid levels were observed in molybdenite roasting facility workers exposed to a TWA concentration of 9.47 mg molybdenum/m^3 as molybdenum trioxide and other oxides (Walravens et al. 1979). The serum uric acid levels were 5.90 mg/dL in the exposed workers and 5.01 mg/dL in the controls; these levels are within the normal range. No significant associations between serum molybdenum levels and serum uric acid levels were found, and none of the workers reported gout-like symptoms.

3.2.1.3 Immunological and Lymphoreticular Effects

No studies have examined immune function following inhalation exposure to molybdenum. Intermediate- and chronic-duration studies in rats and mice did not report histological alterations in the thymus or spleen at molybdenum trioxide levels as high as 67 mg molybdenum/m^3 (NTP 1997).

3.2.1.4 Neurological Effects

No histological alterations were observed in the brain of rats and mice exposed to ≤67 mg molybdenum/m^3 as molybdenum trioxide for 13 weeks or 2 years (NTP 1997); the study did not evaluate neurological function.

3.2.1.5 Reproductive Effects

Following a 13-week exposure to molybdenum trioxide, no alterations in sperm count or motility were observed in rats or mice at concentrations as high as 67 mg molybdenum/m^3 (NTP 1997). No histological alterations were observed in male or female reproductive tissues following exposure to ≤67 mg molybdenum/m^3 for 13 weeks or 2 years (NTP 1997).

3.2.1.6 Developmental Effects

No studies were located regarding developmental effects in humans and animals following inhalation exposure to molybdenum.

3.2.1.7 Cancer

In a case-control study examining the potential association between lung cancer and exposure to 16 potential carcinogens, Droste et al. (1999) did not find a significant increase in lung cancer among workers who self-reported exposure to molybdenum. However, an increased risk of lung cancer was found in workers who self-reported working in industries that could involve exposure to molybdenum (odds ratio of 2.1, 95% confidence interval of 1.2–3.7); the job most often related to molybdenum exposure was processing of stainless steel in the manufacture of metal goods, which could also involve exposure to other carcinogens including chromium, nickel, and arsenic. Limitations of this study, including self-reported exposure and the potential exposure to other lung carcinogens, preclude its use in assessing the potential carcinogenicity of molybdenum.

In the 2-year NTP rat study (NTP 1997), an increase in the combined incidence of alveolar/bronchiolar adenoma or carcinoma was observed in male rats exposed to 67 mg molybdenum/m^3; however, the incidence was within the range of historical controls and NTP considered this to be equivocal evidence of carcinogenic activity. No other concentration-related increases in neoplastic lesions were observed in the rats. In mice, there were significant increases in the incidences of alveolar/bronchiolar carcinoma in males at ≥6.7 mg molybdenum/m^3, alveolar/bronchiolar adenoma or carcinoma in males at 6.7 and 20 mg molybdenum/m^3, alveolar/bronchiolar adenoma in females at 20 and 67 mg molybdenum/m^3, and alveolar/bronchiolar adenoma or carcinoma in females at 67 mg molybdenum/m^3 (NTP 1997). NTP (1997) concluded that the male and female mouse data provided some evidence of molybdenum carcinogenicity.

3.2.2 Oral Exposure

The highest NOAEL values and all LOAEL values from each reliable study for each end point in each species and duration category are recorded in Table 3-2 and plotted in Figure 3-2.

A number of studies have examined the oral toxicity of molybdenum; most were conducted in laboratory animals and most had a limited scope (examined one or two potential targets); the studies evaluated the toxicity of several molybdenum compounds, predominantly sodium molybdate, ammonium heptamolybdate, and ammonium tetrathiomolybdate. Studies have also been conducted in ruminants, particularly cows and sheep; however, these species are not considered suitable models for humans due to differences in interactions between molybdenum, copper, and sulfate in the rumen (see Section 3.5.2 for more information). Studies in rats provide evidence that copper status, particularly the copper content of

Table 3-2. Levels of Significant Exposure to Molybdenum – Oral

Figure key[a]	Species (strain) No./group	Exposure parameters/ concentrations	Parameters monitored	System	NOAEL (mg/kg/day)	Less serious LOAEL (mg/kg/day)	Serious LOAEL (mg/kg/day)	Results	Reference (compound)
ACUTE EXPOSURE									
Systemic									
1	Human 4 M	10 days (F); 0.00237, 0.00771, 0.022 mg/kg/day	UR	Other	0.022			No alterations in urinary uric acid levels	Deosthale and Gopalan 1974 (ammonium molybdate)
2	Rat (Sprague Dawley) 22 M	PND 4-17; 0 or 50 mg/kg/day	BW, HP	Musc/Skel		50		Increased buccal and sulcal enamel lesions following pre-eruptive exposure to molybdenum and administration of a caries promoting diet.	Hunt and Navia 1975 (sodium molybdate)
				Bd Wt	50				
3	Rabbit (New Zealand White) 5 F	14 day (F); 0, 1.2 mg/kg/day	BW, HP	Hepatic		1.2		A 60% increase in serum triglyceride levels was found; no significant alterations in liver or kidney histopathology were found.	Bersenyi et al. 2008 (ammonium heptamolybdate)
				Renal	1.2				
				Bd Wt	1.2				
4	Rabbit (New Zealand White) 5 M	14 day (F); 0, 0.58 mg/kg/day	BW, HP	Hepatic	0.58			No histological alterations in the liver or kidneys or alterations in serum clinical chemistry parameters were observed. The molybdenum in the diet came from carrots grown in molybdenum rich soil.	Bersenyi et al. 2008 (ammonium heptamolybdate)
				Renal	0.58				
				Bd Wt	0.58				
Reproductive									
5	Mouse (ICR) 25 F	14 days (W); 0, 1.3, 2.6, 5.3, and 11 mg/kg/day	HP		5.3[b]	11		Significant increase in the rate of abnormal MII oocytes and decrease in ovarian weights were observed at 11 mg/kg/day. Ovarian hyperemia was observed at 5.3 and 11 mg/kg/day (incidence and statistical significance were not reported).	Zhang et al. 2013 (sodium molybdate)
6	Mouse (ICR) 10 M	14 days; 0, 3, 6, 12, 25, and 49 mg/kg/day	OF		12	25		Significant decreases in relative epididymis weight, sperm concentration, and sperm motility and increase in rate of sperm abnormalities.	Zhai et al. 2013 (sodium molybdate)
7	Rabbit (New Zealand White) 5 F	14 days (F); 0, 1.2 mg/kg/day	BW, HP		1.2			No histological alterations were observed in the ovaries.	Bersenyi et al. 2008 (ammonium heptamolybdate)

Table 3-2. Levels of Significant Exposure to Molybdenum – Oral

Figure key[a]	Species (strain) No./group	Exposure parameters/ concentrations	Parameters monitored	System	NOAEL (mg/kg/day)	Less serious LOAEL (mg/kg/day)	Serious LOAEL (mg/kg/day)	Results	Reference (compound)
8	Rabbit (New Zealand White) 5 M	14 days (F); 0, 0.58 mg/kg/day	BW, HP			0.58		Reduction in germ cells and mature spermatocytes (incidence andr statistical significance were not reported)	Bersenyi et al. 2008 (ammonium heptamolybdate)
INTERMEDIATE EXPOSURE									
Systemic									
9	Rat (Sprague Dawley) 7 M	8 weeks (GW); 0, 40, 80 mg/kg/day	BW, OW, UR	Renal Bd Wt	40 40	80 80		Increases in diuresis and creatinuria, decreases in creatinine clearance, increases in urinary kallikrein (distal tubule enzyme) levels, and increases in relative and absolute kidney weights. Decrease in body weight gain; terminal body weight was 26% lower than in controls	Bompart et al. 1990 (ammonium heptamolybdate)
10	Rat 3-6M, 2-3F (Sprague Dawley)	6 weeks (F); 0 or 70 mg/kg/day	BW, HE	Hemato	70			No alterations in mean hemoglobin levels were found.	Gray and Daniel 1954 (sodium molybdate)
11	Rat (CD) 25M, 25F	59-61 days (males) 22-35 days (females (GW); 0, 0.4, 1.5, 4.4 mg/kg/day	BW, HE	Hemato Bd Wt	1.5 1.5	4.4 4.4		Decreases in body weight gain in males starting at day 50. Decreases in erythrocyte count, hemoglobin concentration, and hematocrit in males.	Lyubimov et al. 2004 (ammonium tetrathiomolybdate)
12	Rat (Wistar) 4M	5 weeks; 0 or 74 mg/kg/day	BW, EA	Bd Wt		74		36% decrease in body weight gain	Mills et al. 1958 (sodium molybdate)
13	Rat (Sprague Dawley) 10M, 10F	90 days (F); 0, 5, 17, or 60 mg/kg/day	CS, BW, BC, HE, FI, GN, HP, OW	Resp Cardio Gastro Hemato Renal Endocr Ocular Bd Wt	60 60 60 60 17 60 60 17	 60 60		15.2% lower terminal body weight in males; slight diffuse hyperplasia in the renal proximal tubules in 2/10 female rats exposed to 60 mg/kg/day.	Murray et al. 2013 (sodium molybdate)

Table 3-2. Levels of Significant Exposure to Molybdenum – Oral

Figure key[a]	Species (strain) No./group	Exposure parameters/ concentrations	Parameters monitored	System	NOAEL (mg/kg/day)	Less serious LOAEL (mg/kg/day)	Serious LOAEL (mg/kg/day)	Results	Reference (compound)
14	Rat (Druckery) 10M	5 days/week 60 days (GW); 0, 4.7, 14, 24 mg/kg	BW	Bd Wt	24			No significant alterations in body weight gain were observed	Pandey and Singh 2002 (sodium molybdate)
15	Rat (Wistar) 6M	9 weeks (W); 0 or 100 mg/kg/day	BW, BI, OW	Cardio Bd Wt Metab	100 100 100			Slight decrease (approximately 4%) in systolic blood pressure. No significant alterations in blood triglyceride, glucose, or insulin levels.	Peredo et al. 2013 (sodium molybdate)
16	Rat (Wistat) 10M or 5M, 5F	4-5 weeks (F); 0 or 110 mg/kg/day	BW, EA	Bd Wt		110		46-48% decrease in body weight gain; no feed intake data were provided.	Van Reen and Williams 1956 (sodium molybdate)
17	Rat (NMRI-D) 17-18 NR	5 weeks; 0, 2, 4, and 8 mg/kg/day	HP	Musc/Skel	8			No significant alterations in the number of carious teeth and the severity of carious lesions	Van Reen et al. 1962 (sodium molybdate)
18	Rat (Wistar) 8 (sex not reported	6 weeks; 0, or 85 mg/kg/day	BW, EA	Bd Wt	85			No alteration in body weight gain was observed and there was no effect on the ability to acetylated p-aminobenzoic acid. An increase in liver alkaline phosphatase levels was observed. Feed intake of control group was matched to molybdenum group.	Williams and Van Reen 1956 (sodium molybdate)
19	Rat (Wistar) 8 (sex not reported)	6 weeks; 0, 90, 144, and 185 mg/kg/day	BW, EA	Bd Wt		90		Decreases in body weight gain of 22, 44, and 60% were observed in the 90, 144, and 185 mg/kg/day groups; decreases in feed intake were also observed in these groups.	Williams and Van Reen 1956 (sodium molybdate)
20	Rat (Sprague Dawley) 10F	8 weeks (W); 0,0.015, 0.076, 0.15, 0.30, 0.76, and 1.5 mg/kg/day	BW, EA, OW	Bd Wt	1.5			No significant differences in terminal body weights were observed.	Yang and Yang 1989 (sodium molybdate)

Table 3-2. Levels of Significant Exposure to Molybdenum – Oral

Figure key[a]	Species (strain) No./group	Exposure parameters/ concentrations	Parameters monitored	System	NOAEL (mg/kg/day)	Less serious LOAEL (mg/kg/day)	Serious LOAEL (mg/kg/day)	Results	Reference (compound)
21	Rabbit (Dutch) 2-5 M,F	30-84 days (F); 0, 7.1, 25, 54, 120, 240 mg/kg/day	CS, LE, BW, HE	Hemato Dermal Bd Wt	25 25 25	54 54	 120	Weight loss was observed in the 120 and 240 mg/kg/day groups. Anemia was observed in 2/5, 5/5, and 4/5 rabbits in the 54, 120, and 240 mg/kg/day groups and in no rabbits at lower doses. Alopecia was observed in 4/5 and 4/5 rabbits in the 54 and 120 mg/kg/day groups; not observed at lower doses or in the 240 mg/kg/day group.	Arrington and Davis 1953 (sodium molybdate)
Reproductive Effects									
22	Rat (Sprague Dawley) 21F	8 weeks (W); 0, 0.76, 1.5, 7.6, and 15 mg/kg/day	BW, WI, OF		0.76[c]	1.5		Prolonged estrus phase (6-12 hours) of the estrous cycle observed at ≥1.5 mg/kg/day. No effect on fertility was observed.	Fungwe et al. 1990 (sodium molybdate)
23	Rat (Long Evans) 4M, 4F	At least 8 weeks (F); 0 or 7 mg/kg/day	BW, HE		7			All rats produced litters; rats were maintained on a high copper diet..	Jeter and Davis 1954 (sodium molybdate)
24	Rat (CD) 25M, 25F	59-61 days (males) 22-35 days (females) (GW); 0, 0.4, 1.5, 4.4 mg/kg/day	OF, HP		1.5	4.4		Decreases in sperm motility and sperm count, and increased sperm morphological alterations; histological alterations in spermatogenesis in 25/25 males. No alterations in female reproductive parameters.	Lyubimov et al. 2004 (ammonium tetrathiomolybdate)
25	Rat (Sprague Dawley) 10M, 10F	90 days (F); 0, 5, 17, or 60 mg/kg/day	CS, BW, BC, HE, FI, GN, HP, OW		17	60		Significant decrease in the percentage of progressively motile sperm; no alterations in overall percentage of motile sperm, spermatid or sperm counts, or sperm morphology. No alterations in vaginal cytology, estrus cycle, or histopathology of male or female reproductive organs	Murray et al. 2013 (sodium molybdate)

Table 3-2. Levels of Significant Exposure to Molybdenum – Oral

Figure key[a]	Species (strain) No./group	Exposure parameters/ concentrations	Parameters monitored	System	NOAEL (mg/kg/day)	Less serious LOAEL (mg/kg/day)	Serious LOAEL (mg/kg/day)	Results	Reference (compound)
26	Rat (Druckery) 10M	5 days/week 60 days (GW); 0, 4.7, 14, 24 mg/kg			4.7	14		Decreases in sperm count and sperm motility and increases in sperm abnormalities were observed at 14 mg/kg and higher. Degeneration of seminiferous tubules were observed in the testesat 24 mg/kg (incidence and statistical significance were not reported.	Pandey and Singh 2002 (sodium molybdate)
27	Rat (Druckery) 20M	5 days/week 60 days (GW); 0 or 14 mg/kg	DX, FX			14		Decrease in fertility (60% versus 80% in controls) and increased pre-implantation losses	Pandey and Singh 2002 (sodium molybdate)
Developmental Effects									
28	Rat (long Evans) 4M, 4F	At least 14 weeks (F); 0 or 7 mg/kg/day	BW, HE		7			All rats produced litters and there were no alterations in birth weight or average weight at weaning.	Jeter and Davis 1954 (sodium molybdate).
29	Rat (CD) 25M, 25F	59-61 days (males) 22-35 days (females) (GW); 0, 0.4, 1.5, 4.4 mg/kg/day	DX		4.4			No effects on resorptions, pre- or post-implantation losses or viable fetuses	Lyubimov et al. 2004 (ammonium tetrathiomolybdate)
30	Rat (Sprague Dawley) 25F	GD6-20 (F); 0, 2.8, 9.8, 20.0, and 37.5 mg/kg/day	DX		37.5			No effects on resorptions, post-implantation losses, fetal body weights, or occurrence of fetal malformations.	Murray et al. 2014 (sodium molybdate)
31	Rat (Druckery) 20M	5 days/week 60 days (GW); 0 or 14 mg/kg	DX, FX			14		Increased post-implantation losses, increased resorptions, decreased number of live fetuses, and decreases in fetal weight and crown-rump length. Males mated with unexposed females	Pandey and Singh 2002 (sodium molybdate)

Table 3-2. Levels of Significant Exposure to Molybdenum – Oral

Figure key[a]	Species (strain) No./group	Exposure parameters/ concentrations	Parameters monitored	System	NOAEL (mg/kg/day)	Less serious LOAEL (mg/kg/day)	Serious LOAEL (mg/kg/day)	Results	Reference (compound)

[a]The number corresponds to entries in Figure 3-2.
[b]Used to derive an acute-duration oral minimal risk level (MRL) of 0.053 m molybdenum/kg/day based on the NOAEL of 5.3 mg molybdenum/kg/day and an uncertainty factor of 100 (10 for extrapolation from animals to humans and 10 for human variability).
[c]Used to derive an intermediate-duration oral MRL of 0.0076 mg molybdenum/kg/day based on the NOAEL of 0.76 mg molybdenum/kg/day and an uncertainty factor of 100 (10 for extrapolation from animals to humans and 10 for human variability).

BC = biochemistry; BW = body weight; Cardio = cardiovascular; CS = clinical signs; d = day(s); DX = developmental; EA = enzyme activity; Endocr = endocrine; F = female(s); F = food; FI = feed intake; FX = function testing; Gastro = gastrointestinal; GN = gross necropsy; GW = gavage in water; HE = hematology; Hemato = hematology; HP = histopathology; hr = hour(s; MRL = Minimal Risk Level; NS = not specified; Musc/Skel = mucsculoskeletal; OP = ophthalmology; OW = organ weight; Resp = respiratory; sec = second(s); UR = urinalysis; WI = water intake; wk = week(s)

Figure 3-2. Levels of Significant Exposure to Molybdenum - Oral
Acute (≤ 14 days)

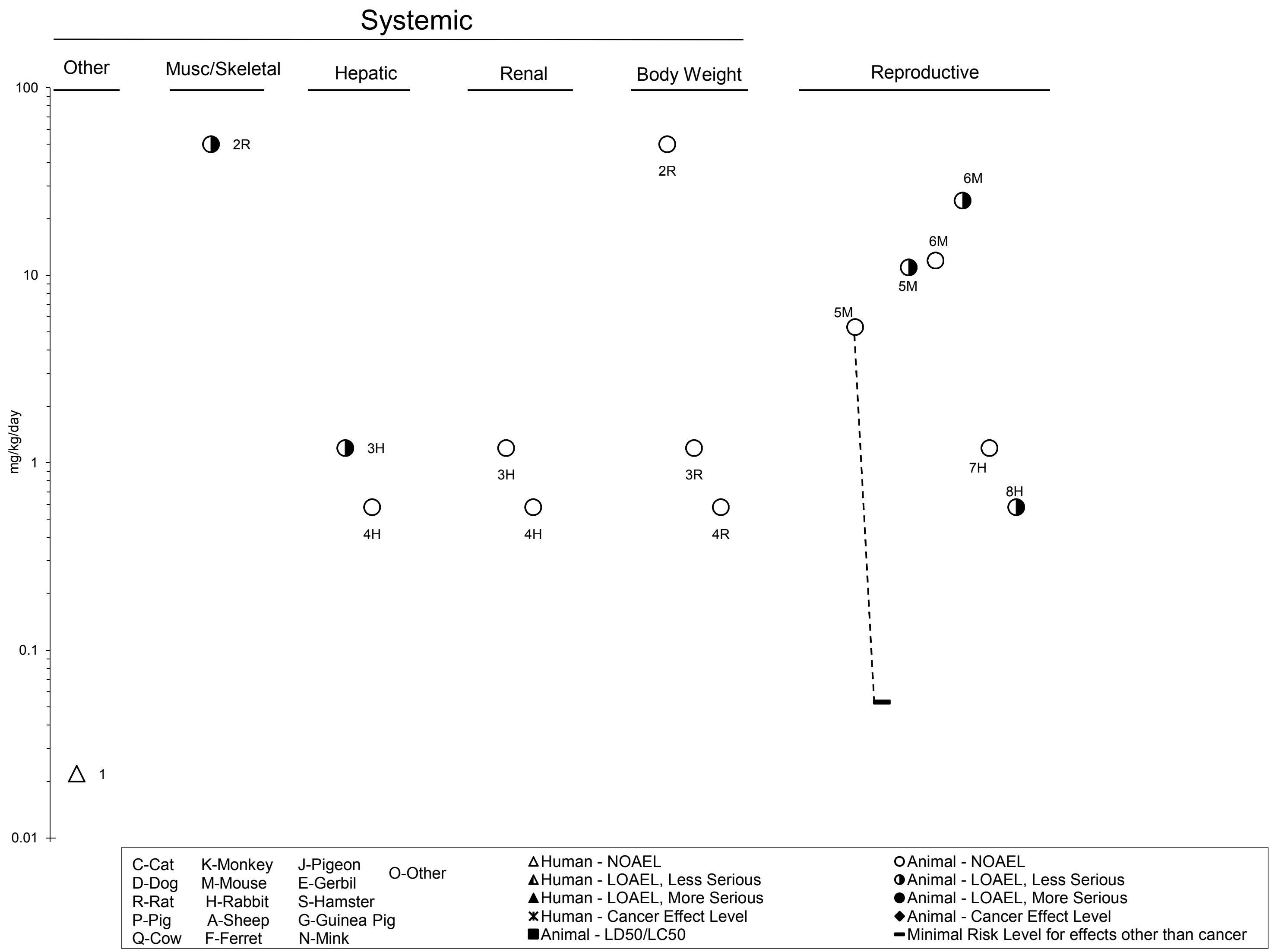
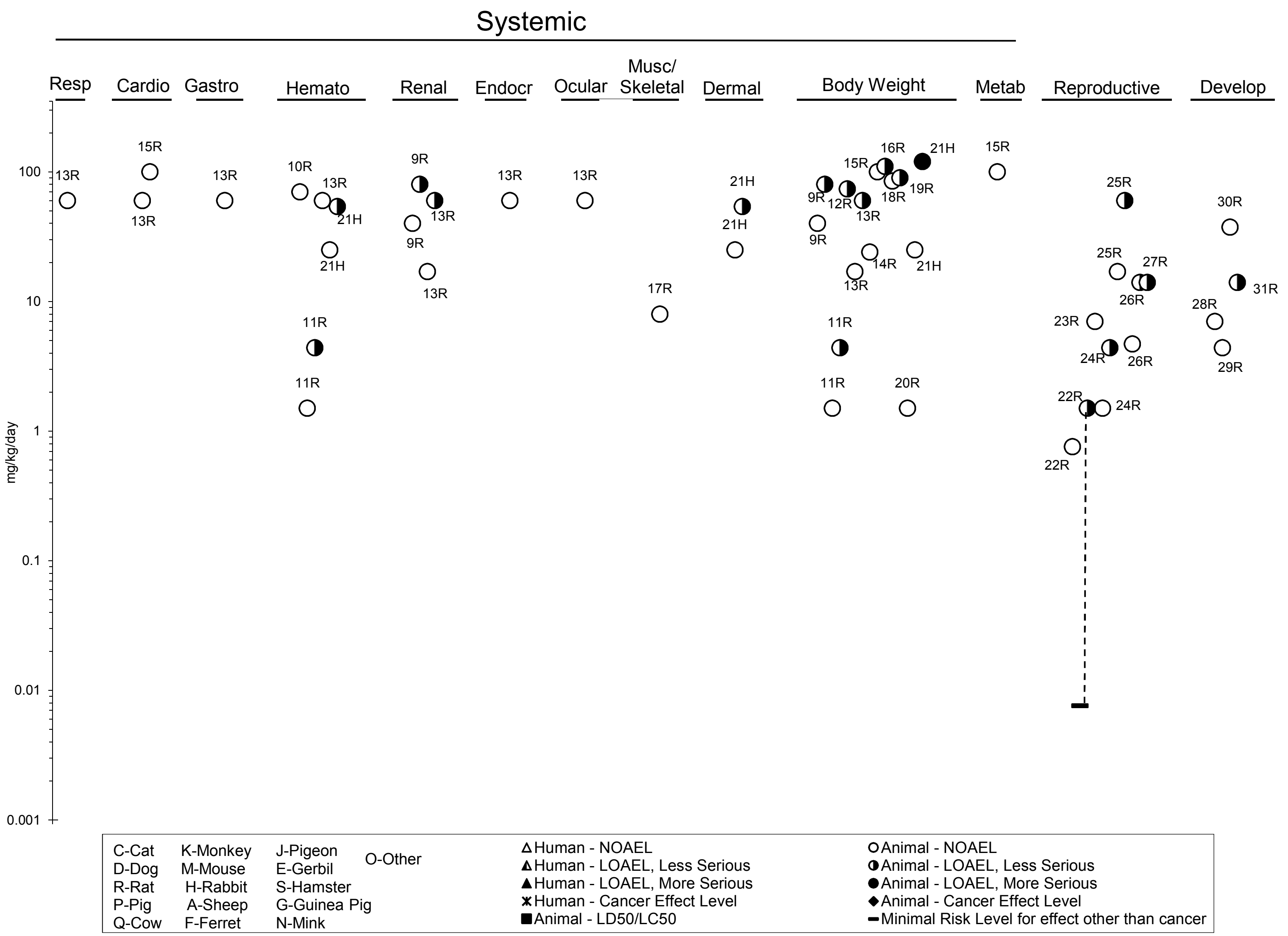


Figure 3-2. Levels of Significant Exposure to Molybdenum - Oral *(Continued)*

Intermediate (15-364 days)



the diet, can influence the toxicokinetics of molybdenum and possibly its toxicity. The current recommended dietary copper concentrations of 5, 6, and 3 ppm have been set for rats, mice, and rabbits, respectively (NAS 1977, 1995); for rats and mice, a copper dietary level of 8 ppm has been established to support gestation and lactation (NAS 1995). Administration of 150 and/or 500 mg/kg molybdenum in the diet for up to 6 weeks to rats fed a copper-deficient or copper-adequate diet resulted in profound differences in the distribution of copper and molybdenum in the plasma, liver, and kidneys (Nederbragt 1980, 1982). For example, at a molybdenum dietary concentration of 150 mg/kg, molybdenum levels in the liver and kidneys were 3.5 and 9 times higher, respectively, in the copper-adequate rats as compared to 6 and 4 times higher in the copper-deficient rats. Additionally, the relative increase in copper levels in the liver and kidneys was greater in the rats fed the copper-deficient diet, as compared to those fed the copper-adequate diet. Administration of tetrathiomolybdate compounds, as compared to molybdate compounds, results in more dramatic shifts in copper levels in rats fed copper adequate diets (Mills et al. 1981a). Since it is not known whether the differences in the distribution of copper and molybdenum influence the molybdenum toxicity, studies in which the laboratory animals were fed a basal diet with inadequate copper levels are clearly identified in the text, are discussed separately from studies in which there was adequate dietary copper levels, and are not included in the LSE table or figure. Additionally, laboratory animal studies in which the diet provided an inadequate amount of copper are not likely to be a good model for the U.S. population since the median copper intake of adults in the United States exceeds the nutritional requirement (RDA) for copper (NAS 2001).

3.2.2.1 Death

Several oral studies have reported deaths in rabbits exposed to molybdenum. Mortality rates of 42–100% were observed in rabbits exposed to 59–120 mg molybdenum/kg/day for intermediate durations (Arrington and Davis 1953; Robinson et al. 1969; Valli et al. 1969; Widjajakusuma et al. 1973). Although the causes of death were not reported, anorexia, body weight loss, and anemia were observed in most of the studies at the lethal concentrations, suggesting that the deaths may be related to a functional copper deficiency. The copper content of the diet was adequate in the Arrington and Davis (1953) study and was not reported in the Widjajakusuma et al. (1973), Robinson et al. (1969), and Valli et al. (1969) studies. No deaths have been reported in rat studies (e.g., Lyubimov et al. 2004; Murray et al. 2013, 2014; Pandey and Singh 2002).

3.2.2.2 Systemic Effects

Respiratory Effects. Only one animal study examined the respiratory tract following oral exposure to molybdenum. No lesions were observed in the lungs of rats exposed to ≤60 mg molybdenum/kg/day as sodium molybdate in the diet for 90 days (Murray et al. 2013).

Cardiovascular Effects. Using the NHANES dataset (2009–2012), Shiue and Hristova (2014) found a significant positive association between urinary molybdenum levels and high blood pressure among adults after adjusting for potential confounders (adjusted odds ratio of 1.45; 95% confidence interval of 1.04–2.02). The investigators estimated that molybdenum accounted for 6.3% of the variance in the population risk and significant associations were also found for other metals including cesium, lead, platinum, antimony, arsenic, and tungsten and industrial pollutants including phthalates, bisphenol A, and parabens. In a population-based study examining the possible association between municipal water constituents and cardiovascular mortality in residents of 94 large cities in the United States, Schroeder and Kraemer (1974) found a weak negative correlation between arteriosclerotic heart disease deaths and molybdenum levels among white males, but not white females or nonwhite males or females. The mean concentration of molybdenum in the municipal water samples was 1.25 µg/L (0.00003 mg molybdenum/kg/day, assuming a water intake of 2 L/day and body weight of 70 kg) with a range of 0–16 µg/L. These studies appear to provide conflicting results, with one study suggesting a beneficial effect of increased molybdenum (Schroeder and Kraemer 1974) and the other a detrimental effect (Shiue and Hristova 2014). However, a number of etiological factors contribute to the overall risk of both diseases and the contribution of molybdenum to the overall risk was low in both studies.

No alterations in heart weight or histopathology were observed in rats ingesting ≤60 mg molybdenum/kg/day as sodium molybdate for 90 days (Murray et al. 2013). Peredo et al. (2013) reported a slight decrease (approximately 4%) in systolic blood pressure in rats exposed to 100 mg molybdenum/kg/day as sodium molybdate in drinking water for 9 weeks; this slight decrease in blood pressure was not considered biologically relevant.

Gastrointestinal Effects. No histological alterations were observed in the gastrointestinal tract of rats exposed to ≤60 mg molybdenum/kg/day as sodium molybdate in the diet for 90 days (Murray et al. 2013). In contrast, Fell et al. (1979) reported soft feces and diarrhea and a number of histological alterations in the gastrointestinal tract of rats exposed for up to 21 days to 0.5 mg molybdenum/kg/day as ammonium tetrathiomolybdate in the diet (diet provided an inadequate amount of copper). The alterations included shortening of the gastric pits with a reduction in the amount of mucin in the stomach, an increase in the crypt to villus ratio in the small intestine due to a lengthening of the crypts, edema of the lamina propria in the ileum, and submucosal edema of the cecum resulting in a thickening of the cecum but no effect on the brush border. However, the investigators did not provide incidence data, which limits the assessment of these alterations.

Hematological Effects. In general, the hematological system does not appear to be a target of molybdenum toxicity when the basal diet contains adequate levels of copper. In rats exposed to sodium molybdate or ammonium heptamolybdate, the highest NOAEL values for hematological alterations ranged from 3.35 to 150 mg molybdenum/kg/day for intermediate-duration exposure (Brinkman and Miller 1961; Franke and Moxon 1937; Gray and Daniel 1954; Hunt and Navia 1973; Jeter and Davis 1954; Johnson et al. 1969; Murray et al. 2013). One study reported decreases in erythrocyte counts, hemoglobin, and hematocrit in rats exposed to 4.4 mg molybdenum/kg/day as ammonium tetrathiomolybdate administered via gavage for 59–61 days (Lyubimov et al. 2004). Although the basal diet contained the NRC's recommended amount of copper (NAS 1995), hematological effects were not observed in rats exposed to the same molybdenum dose receiving a diet containing additional copper (110 ppm), suggesting that the hematological effects may have been secondary to a molybdenum-induced copper deficiency (anemia is a sign of copper deficiency). In young rabbits, exposure to 54 mg molybdenum/kg/day as sodium molybdate in the diet resulted in anemia (Arrington and Davis 1953). Even though the reported copper concentration in the diet exceeded the more recently recommended standard of 3 ppm (NAS 1977), administration of additional copper resulted in increases in hemoglobin levels. In a similar study using mature rabbits, anemia was observed in one of two rabbits exposed to 30 mg molybdenum/kg/day as sodium molybdate in the diet (Arrington and Davis 1953). Decreases in hemoglobin levels and packed cell volume were also observed in two other rabbit studies (Valli et al. 1969; Widjajakusuma et al. 1973) in which rabbits were exposed to 77 or 59 mg molybdenum/kg/day in the diet for approximately 4 weeks. Mortality was observed in both studies and neither study reported the copper levels of the basal diet; Valli et al. (1969) did note that the rabbits were fed a diet with a low copper content. In pigs, no hematological alterations were observed following dietary exposure to 20–100 ppm molybdenum as sodium molybdate or ammonium heptamolybdate in the diet for at least 8 weeks (Gipp et al. 1967; Kline et al. 1973); the studies did not provide sufficient information to allow for an estimation of the molybdenum dose.

Musculoskeletal Effects. A number of animal studies have examined the effect of molybdenum on bone growth and strength and on the promotion of dental caries. Musculoskeletal effects were observed in two studies in which the diet contained at least the recommended level of copper. In a study by Johnson et al. (1969) in which rats were exposed to 150 mg molybdenum/kg/day as sodium molybdate in the diet for 6 weeks (the basal diet contained copper levels that were 3 times higher than the recommended amount), decreases in femur breaking strength (22% less than controls) and tail ring rupture strength (32% less than controls) were observed. Young rabbits exposed to ≥54 mg molybdenum/kg/day as sodium molybdate for 30–84 days exhibited a front limb abnormality characterized by weakness progressing to an inability to "maintain weight and legs spread outward" (Arrington and Davis 1953). This was not observed in mature rabbits exposed to ≤120 mg molybdenum/kg/day as sodium molybdate for at least 54 days (Arrington and Davis 1953). The investigators noted that in three of the seven affected animals, one or both feet bent inward at the carpus joint, the articular surface of the radius was exposed, and the tendon slipped out of normal position. It should also be noted that increases in mortality were also observed in the young rabbits exposed to 54 mg molybdenum/kg/day, and in two of the rabbits with limb abnormalities, administration of additionally copper did not reverse the skeletal effect, although there was improvement of other effects including anemia and body weight gain.

In an acute-duration study, femurs were significantly shorter in rats exposed to 0.6 mg molybdenum/kg/day as ammonium heptamolybdate or ammonium tetrathiomolybdate for 13 days (Parry et al. 1993). No alterations in the width of the growth plate or the bone composition (dry matter content, ash content, or percentage of calcium or phosphorus) were found. Similar findings were found in a 26-day study conducted by Parry et al. (1993); significant decreases in femur length were noted in rats exposed to 0.6 mg molybdenum/kg/day as ammonium heptamolybdate or ammonium tetrathiomolybdate in the diet. Although no direct comparisons were made between the two molybdenum groups, the magnitude of the decrease in femur length, as compared to the controls, was greater in the tetrathiomolybdate group. Increases in growth plate width were also observed in the rats exposed to ammonium tetrathiomolybdate, but not in rats exposed to ammonium heptamolybdate. In both experiments, the rats were fed a basal diet with inadequate copper levels (60% of the recommended concentration); in the ammonium tetrathiomolybdate study, plasma and liver copper levels indicated that the animals were extremely copper deficient. Spence et al. (1980) examined the development of widening of the epiphyseal growth plate over time in rats exposed to 1 mg molybdenum/kg/day as ammonium tetrathiomolybdate in the diet for 2–21 days. The study found cartilaginous dysplasia at the epiphyseal growth plate with impaired or arrested endochondral ossification, increases in periosteal osteogenesis and production of large amounts of disorganized bone, resorption of most trabecular bone, hemorrhaging within and tearing of tendons and ligaments, rotation and slipping of the distal epiphysis in the femur without fracture, and impaired fibrogenesis at ligamentous attachments to bone. A thickening and widening of the epiphyseal growth plate was observed in the distal femur and proximal and in the epiphyses of the humeral head, distal radius, and ulna; these effects were observed within the first 2 weeks of the study. Other morphological alterations in the bone were observed after 7 days of exposure; these included loss of alignment of hypertrophic cells at the periphery of the epiphyseal cartilage and localized increases in cell numbers. In rats allowed to recover for 39 days following the 21-day exposure period, osteogenesis and fibrogenesis returned to normal, and remodeling and growth returned (although some abnormal cartilage and bone were present). As with the Parry et al. (1993) study, the rats in the Spence et al. (1980) study were fed a basal diet containing an inadequate amount of copper (60% of the recommended level). Fejery et al. (1983) found an increase in femur breaking strength in rats exposed to 0.17 or 1.7 mg molybdenum/kg/day (copper content of the diet was not reported), which was considered a beneficial effect; at 17 mg molybdenum/kg/day, breaking strength was similar to controls. However, if the rats were maintained on a protein-deficient diet, decreases in breaking strength were observed at 1.7 and 17 mg molybdenum/kg/day. In rabbits exposed to a lethal concentration of sodium molybdate (77 mg molybdenum/kg/day) in the diet for 4 weeks, fractures of the humeral bone epiphyses were observed in 50% of the animals (Valli et al. 1969). Other effects included longitudinal widening of the epiphyseal cartilage, marked reduction in trabecular bone, irregularly arranged spicules, and irregular metaphyseal calcification. In addition, the investigators noted that there was marked muscular degeneration in the pelvic limbs in 25% of the rabbits. The copper content of the basal diet was not reported in this study, although the investigators noted that the diet had a low copper content.

Alterations in tooth enamel and caries formation have also been observed in laboratory animals exposed to molybdenum. In rat pups administered 50 mg molybdenum/kg/day as sodium molybdate via gavage on postnatal days (PNDs) 4–17 (prior to tooth eruption) and fed a caries-promoting diet on PNDs 18–35, a 25% increase in buccal enamel lesion and 85 and 12.5% increases in lesions penetrating to the buccal and sulcal dentine-enamel junctions, respectively, were observed in the mandibular molars (Hunt and Navia 1975). Fejery et al. (1983) reported biphasic alterations in incisor tooth enamel microhardness in rats exposed to sodium molybdate in drinking water for 6 weeks (the copper content of the basal diet was not reported). At 1.7 mg molybdenum/kg/day, there were increases in microhardness (6–7% increases in surface and deep enamel microhardness), which was considered a beneficial effect. However, at 17 mg molybdenum/kg/day, tooth surface and deep enamel microhardness was decreased by 14.5 and 7.5%, respectively. The study also examined the possible effect of a low protein diet (3% in the low-protein groups compared to 18% in the protein-adequate groups) and found that the beneficial effect of 1.7 mg molybdenum/kg/day did not occur in the rats in the low-protein diet; a 4–5% reduction in microhardness was found at 1.7 mg/kg/day. Van Reen et al. (1962) did not find increases in dental caries in weanling NMRI-D rats (a caries susceptible strain) exposed to 8 mg molybdenum/kg/day as sodium molybdate for 5 weeks (the basal diet provided adequate copper levels).

Hepatic Effects. There are limited data on the hepatotoxicity of molybdenum in humans. Using the NHANES 2007–2008 data, Mendy et al. (2012) found a significant association between urinary molybdenum levels and the risk of having a self-reported liver condition (odds ratio of 3.09; 95% confidence interval of 1.24–7.73). The geometric mean urinary molybdenum level of the population was 43.8 μg/g creatinine (95% confidence interval of 42.61–45.19); the investigators did not report the urinary concentration associated with the increased risk of liver conditions. This study does not establish causality between molybdenum exposure and liver damage, and significant associations were also found between uranium and cesium levels and liver conditions.

The liver does not appear to be a sensitive target of molybdenum toxicity in laboratory animals, although effects have been observed at higher doses. No histological alterations were observed in livers of rabbits exposed to 1.2 mg molybdenum/kg/day as ammonium heptamolybdate in the diet for 14 days (Bersenyi et al. 2008), rabbits exposed to 0.58 mg molybdenum/kg/day from carrots grown in ammonium heptamolybdate rich soil, or rats exposed to 60 mg molybdenum/kg/day in the diet for 90 days (Murray et al. 2013); these are the only studies that included histological examination of the liver. The Bersenyi et al. (2008) female rabbit study did not find alterations in serum alanine or aspartate aminotransferases levels, γ-glutamyl transferase, alkaline phosphatase, or cholesterol levels; however, a 60% increase in serum triglyceride levels was found at 1.2 mg molybdenum/kg/day. In contrast, the Murray et al. (2013) study examined similar serum clinical chemistry parameters (including triglyceride levels) and did not find any significant alterations. A series of studies conducted by Rana and associates have also reported some liver alterations in rats exposed to 300–490 mg molybdenum/kg/day as ammonium molybdate. The reported alterations included increases in total lipid levels (Rana et al. 1980; Rana and Kumar 1980b, 1980c), decreases in "total carbohydrate" (Rana and Kumar 1980c), decreases in glycogen content (Rana et al. 1985), and increases in serum alanine aminotransferase and aspartate aminotransferase activities (Rana and Chauhan 2000). The addition of 100 mg/kg body weight/day copper to the basal diet (approximately 5 ppm) appeared to reverse the effects of molybdenum on hepatic lipid and carbohydrate levels (Rana and Kumar 1980c). There was low confidence in these studies due to the poor reporting of the study design (including route of oral administration, whether the dose was reported in terms of molybdenum or ammonium molybdate, and copper content of the diet), the lack of histological examination of the liver, and the reported body weight losses (Rana et al. 1980; Rana and Chauhan 2000); body weight was not assessed in every study.

Renal Effects. The available data from laboratory animal studies suggest that the kidney may be a target of molybdenum toxicity. Most of these studies involved exposure to ammonium molybdate or ammonium heptamolybdate and it is possible that the renal effects may be due to the ammonium ion rather than the molybdate. In the only available acute-duration study, no histological alterations were observed in the kidneys of female rabbits exposed to 1.2 mg molybdenum/kg/day as ammonium heptamolybdate in the diet for 14 days (Bersenyi et al. 2008) or male rabbits exposed to 0.58 mg molybdenum/kg/day from carrots grown in ammonium heptamolybdate-rich soil for 14 days (Bersenyi et al. 2008). Murray et al. (2013) reported a slight diffuse hyperplasia in the renal proximal tubules in 2/10 female rats exposed to 60 mg molybdenum/kg/day as sodium molybdate in the diet for 90 days; no renal lesions were observed in females exposed to 60 mg molybdenum/kg/day for 90 days and allowed to recover for 60 days. No alterations were observed in the male rats. Although the incidence was low, the investigators considered it to be treatment-related because it is an uncommon finding in female rats of this age. Degenerative changes in the kidneys were noted in male rats exposed to 240 mg molybdenum/kg/day as ammonium molybdate (Bandyopadhyay et al. 1981). It should be noted that the food intake in the molybdenum group was paired to another group of rats fed a low-protein diet and exposed to molybdenum; the basal diet likely provided adequate copper levels. No other studies included histological examination of the kidneys.

Several studies reported alterations in serum and urinary parameters that could be suggestive of altered renal function. Diuresis and creatinuria and a decrease in creatinine clearance were observed in rats administered via gavage 80 mg molybdenum/kg/day as ammonium heptamolybdate for 8 weeks (Bompart et al. 1990). The study did not find significant alterations in urinary protein or glucose levels. Studies by Rana and associates have reported increases in total lipid levels in the kidneys (Rana et al. 1980; Rana and Kumar 1980c), decreases in “total carbohydrate” levels in the kidney (Rana and Kumar 1980c), increases in serum urea and urinary albumin levels (Rana and Kumar 1983), and increases in urine specific gravity (Rana and Kumar 1983) in rats exposed to high doses of ammonium molybdate (300–490 mg molybdenum/kg/day). The addition of copper (approximately 5 ppm) to the basal diet appeared to reverse the increased lipid and decreased carbohydrate levels (Rana and Kumar 1980c). As noted in the hepatic effects section, there is low confidence in these studies and the results should be interpreted cautiously.

Endocrine Effects. The possible association between molybdenum and thyroid effects was investigated in adults (subjects did not report having thyroid disease, thyroid cancer, or taking thyroid medication on a medical questionnaire completed at the blood sampling) using the NHANES 2007–2008 data set (Yorita Christensen 2013). Significant associations between decreased levels of triidothyronine (free and total) and thyroxine (free) and higher urinary molybdenum levels were found. Although the study found associations, these data are inadequate for establishing causality. A study of men at a fertility clinic found a significant inverse relationship between blood molybdenum levels and prolactin levels (Meeker et al. 2009); the men were categorized into three groups based on blood molybdenum levels (<70th percentile, 70th–85th percentile, and >85th percentile). The study did not find a significant association with thyroid stimulating hormone and blood molybdenum levels.

In animal studies, increases in serum cortisol, prolactin, and follicle stimulating hormone levels were found in male rats administered 240 mg molybdenum/kg/day as ammonium molybdate for 4 weeks (Bandyopadhyay et al. 1981); as noted in the renal effects section, food intake was matched to a low-protein molybdenum group. Murray et al. (2013) did not find increases in histological alterations in the adrenal glands, pituitary gland, or thyroid of rats exposed to 60 mg molybdenum/kg/day as sodium molybdate in the diet for 90 days. Several thyroid effects were reported in rabbits exposed to 59 mg molybdenum/kg/day as sodium molybdate in the diet for 25–31 days (Widjajakusuma et al. 1973). The investigators did not report the copper content of the diet; it is likely to be low based on the severe decreases in body weight, hematological parameters, and increased mortality. The effects included decreases in thyroxine secretion rates; decreases in follicle size (height and diameter); atrophy of the follicular epithelium, colloids, and stroma; and degenerative alterations in the follicular epithelium and interfollicular connective tissue. With the exception of the degenerative changes, similar, but less prominent, thyroid effects were also observed in pair-fed controls, suggesting that the resulted decreases in food intake and body weight contributed to the thyroid toxicity.

Dermal Effects. There are limited data on the dermal toxicity of molybdenum following oral exposure. In the first study of weanling rabbits (Arrington and Davis 1953), alopecia and slight dermatosis were observed in four of five rabbits exposed to 54 mg molybdenum/kg/day as sodium molybdate in the diet for 84 days; no dermal effects were observed at 25 mg molybdenum/kg/day. In another study by this group, alopecia and slight dermatosis were observed in one of two mature rabbits exposed to 30 mg molybdenum/kg/day as sodium molybdate. Anemia was also observed at these doses. In the study of weanling rabbits, administration of additional copper resulted in a return to a normal hair coat, suggesting that copper insufficiency, possibly molybdenum induced, was a contributing factor to the dermal toxicity. Johnson et al. (1969) reported decreases (25% lower than controls) in skin rupture strength in rats exposed to 150 mg molybdenum/kg/day as sodium molybdate in the diet for 6 weeks.

Ocular Effects. No ocular lesions were observed in rats exposed to 60 mg molybdenum/kg/day as sodium molybdate in the diet for 90 days (Murray et al. 2013); no other studies examined ocular end points.

Body Weight Effects. A large number of animal studies have reported alterations in body weight following acute- or intermediate-duration exposure to molybdenum. Large differences in terminal body weights between controls and molybdenum-exposed groups and weight loss have been reported in many studies in which the basal diet did not provide adequate levels of copper (Brinkman and Miller 1961; Fell et al. 1983; Johnson and Miller 1961; Ostrom et al. 1961; Sasmal et al. 1968; Van Reen 1959). In one study, exposure to 500 mg molybdenum/kg/day as sodium molybdate resulted in weight loss in rats (Sasmal et al. 1968); no alterations in weight loss were observed at 50 or 100 mg molybdenum/kg/day. The weight loss began early in the study; the animals weighed about 35% less than at the start of the study after 1 week of exposure. In another study by this group (Sasmal et al. 1968), exposure to 50 mg molybdenum/kg/day as ammonium molybdate resulted in weight loss. Although the study suggests differences between the two molybdenum compounds, the very low copper content of the diet (no additional copper was added to the purified diet) precludes extrapolating these data to other conditions. In another study comparing molybdenum compounds, a 10-day dietary exposure to 0.6 mg molybdenum/kg/day as ammonium tetrathiomolybdate resulted in a 10% decrease in body weight in rats; however, no alterations in body weight gain were observed in rats exposed to 0.6 mg molybdenum/kg/day as ammonium heptamolybdate under the same exposure conditions (Parry et al. 1993). The copper content of the diet was 3 ppm, which is lower than the recommendation of 5 ppm in the diet (NAS 1995).

Decreases in body weight gain have been observed in studies in which the basal diet provided a nutritionally adequate level of copper (Arrington and Davis; 1953; Bompart et al. 1990; Jeter and Davis 1954; Johnson 1969; Lyubimov et al. 2004; Mills et al. 1958; Murray et al. 2013; Van Reen and Williams 1956). Studies in rats in which the basal diet contained at least twice the amount of copper recommended by the NAS (1995) reported significant decreases in body weight gain at 60–110 mg molybendum/kg/day as sodium molybdate or ammonium heptamolybdate in intermediate-duration studies (Bompart et al. 1990; Mills et al. 1958; Murray et al. 2013; Van Reen and Williams 1956; Williams and Van Reen 1956). The magnitude of the decrease in body weight gain appeared to be related to the dose, with approximately 15% decreases observed at 60 mg molybdenum/kg/day and 48% decreases observed at 110 mg molybdenum/kg/day. Administration of ammonium tetrathiomolybdate resulted in a very low LOAEL of 4.4 mg molybdenum/kg/day for decreases in body weight gain (Lyubimov et al. 2004); there are insufficient data to assess whether this is evidence of differences between molybdenum compounds. Decreases in food intake have also been reported in dietary exposure studies (Murray et al. 2013; Williams and Van Reen 1956) and a gavage study (Lyubimov et al. 2004). Williams and Van Reen (1956) found that when the control group food intake was matched to the molybdenum group, body weight was not adversely affected after 5 weeks of exposure to 85 mg molybdenum/kg/day as sodium molybdate. However, when the control group had *ad libitum* access to food, exposure to 90 mg molybdenum/kg/day as sodium molybdate resulted in a 22% decrease in body weight gain. In contrast, Murray et al. (2013) found a decrease in food conversion efficiency suggesting that factors other than the reduction in feed intake resulted in the decreased body weight gain. Similarly, in a study by Johnson and Miller (1961) in which the basal diet contained 3.2 ppm copper, large differences (50–60% less) in food intake were observed between the control group and the group exposed to 20 ppm molybdenum/kg/day as sodium molybdate. However, when the control intake was matched to the molybdenum group's intake, significant decreases in body weight gain were still observed.

Metabolic Effects. The potential of molybdenum to induce metabolic alterations has not been fully investigated. Two studies in rats did not find significant alterations in serum glucose levels following intermediate-duration exposure to 60 or 100 mg molybdenum/kg/day (Murray et al. 2013; Peredo et al. 2013); additionally, serum insulin levels were not altered by exposure to 100 mg molybdenum/kg/day (Peredo et al. 2013). Prakash (1989) reported decreases in glycogen levels in the hind limb muscles of rats administered 490 mg molybdenum/kg/day as ammonium molybdate via gavage for 30 days. The significance of this effect is difficult to determine since the study did not provide information on body weight gain.

Other Systemic Effects. Koval'skiy et al. (1961) reported a significant increase in blood uric acid levels and symptoms of gout in residents living in an area of Armenia with high levels of molybdenum in the soil and food, as compared to residents living outside of this area. The mean uric acid levels in a subset of the examined population (n=52) was 6.2 mg/dL, as compared to levels in five control subjects who had a mean level of 3.8 mg/dL; the mean uric acid levels were 8.1 mg/dL among the subjects with gout symptoms and 5.3 mg/dL among the exposed subjects without symptoms. The investigators reported that copper intakes (5–10 mg/day) were lower in the high molybdenum area as compared to copper intake for residents outside of this area (10–15 mg/day). It was also noted that gout-like symptoms have not been observed in other high molybdenum areas that have higher copper intakes

(Koval'skiy et al. 1961). Interpretation of the result of this study is limited by the small control group, as compared to the exposed group; lack of information on the selection of controls, particularly if they were matched to the exposed group; and lack of information on diet and alcohol exposure, which could influence uric acid levels. Based on the levels of molybdenum in the foodstuff, the investigators estimated a daily dose of 10–15 mg (0.14–0.21 mg/kg/day assuming a 70-kg body weight). Deosthale and Gopalan (1974) did not find significant increases in urinary uric acid levels in four subjects exposed to a low molybdenum diet for 10 days followed by a high molybdenum diet with an ammonium molybdate supplement for 7 days (TWA molybdenum intake was 0.014 mg molybdenum/kg/day), as compared to uric acid levels when the subjects were fed a low molybdenum diet. A series of studies in Colorado investigated uric acid levels in communities with high molybdenum levels in the drinking water from mine tailings pollution (EPA 1979). Comparisons between subjects living in areas with high molybdenum in the drinking water (80–200 µg/L; approximately 0.002–0.006 mg/kg/day) to those living in areas with lower levels (<40 µg/L; <0.001 mg/kg/day) did not result in any significant differences in serum uric acid levels or urinary molybdenum levels. Another study (EPA 1979) noted that serum uric acid levels were within the normal range in students with an estimated molybdenum intake of 500 µg/day (0.007 mg/kg/day) (EPA 1979). A third study found significant increases in uric acid levels in residents with low molybdenum (20 µg/L; 0.0006 mg/kg/day) levels in the water and in residents with high molybdenum levels (150–200 µg/L; 0.004–0.006 mg/kg/day) in the drinking water; as compared to residents with drinking water levels of 0–50 µg/L (0–0.001 mg/kg/day). The inconsistencies in the results could be explained by the lack of control of several variables including age, sex, alcohol intake, dietary habits, and altitude.

Murray et al. (2013) found a statistically significant decrease in serum uric acid levels in female rats exposed to ≥5 mg molybdenum/kg/day as sodium molybdate in the diet for 90 days; no alterations were observed in male rats exposed to up to 60 mg molybdenum/kg/day. Other statistically significant alterations in serum clinical chemistry parameters noted in the Murray et al. (2013) study include decreases in total protein and calcium at 60 mg molybdenum/kg/day in males and decreases in serum creatinine at ≥5 mg molybdenum/kg/day in females. The investigators noted that the changes in serum clinical chemistry (including uric acid levels) were not considered treatment-related because the alterations were of small magnitude, not dose-related, due to outliers in the controls, and/or were consistent with normal variability. Quantitative data for the serum clinical chemistry parameters were not provided in the published paper.

3.2.2.3 Immunological and Lymphoreticular Effects

No studies were located regarding immunological and lymphoreticular effects in humans and animals following oral exposure to molybdenum.

3.2.2.4 Neurological Effects

There are limited data on the neurotoxicity of molybendum; no human or animal studies were designed to assess sensitive neurological end points. No overt signs of neurotoxicity were observed in laboratory animal studies (e.g., Murray et al. 2013); Murray et al. (2013) did not report any histological alterations in the brain.

3.2.2.5 Reproductive Effects

There are limited data on reproductive effects of molybdenum in humans. The available studies have evaluated correlations between ambient molybdate exposure and reproductive health measures, including semen quality (Meeker et al. 2008) and sex hormone levels (Meeker et al. 2010). Meeker et al. (2008) reported a negative significant association between higher molybdenum blood levels (>85th percentile, based on molybdenum levels in blood) and sperm concentration (adjusted odds ratio of 3.48, 95% confidence interval of 1.12–10.8) after adjustment for potential confounders and other metal exposures. No significant associations were found for sperm morphology (adjusted odds ratio of 2.61, 95% confidence interval of 0.97–7.0) or sperm motility (adjusted odds ratio of 2.24, 95% confidence interval of 0.77–6.49). In another study, Meeker et al. (2010) reported a negative correlation between higher molybdenum blood levels (≥70th percentile) and testosterone and free androgen index (molar ratio of total testosterone sex hormone-binding globulin) levels. The men in these studies, who were recruited from Michigan infertility clinics and were not all considered to be infertile (i.e., their partners may have been infertile), were only exposed to molybdenum from their surroundings. A significant negative association between a biomarker of molybdenum exposure (urinary levels) and serum testosterone levels was also observed in a study of males participating in NHANES (2011–2012) (Lewis and Meeker 2015). The study found a 3.82% decrease in serum testosterone levels when urinary molybdenum levels doubled (after adjustment for age, body mass index [BMI], income, race, and smoking). Although these studies found statistically significant associations, they do not establish causality and the alterations in reproductive parameters may be due to multiple factors rather than only to molybdenum exposure.

Several studies have evaluated the reproductive toxicity in male laboratory animals. Decreases in sperm motility and concentration and increases in sperm morphological changes were observed in rats administered via gavage 4.4 mg molybdenum/kg/day as ammonium tetrathiomolybdate for 59–61 days (Lyubimov et al. 2004) or 14 mg molybdenum/kg/day as sodium molybdate for 60 days (Pandey and Singh 2002), and in mice exposed to 25 mg molybdenum/kg/day as sodium molybdate in the drinking water for 14 days (Zhai et al. 2013). These studies also found decreases in epididymis, seminal vesicle, and/or prostate gland weights (Lyubimov et al. 2004; Pandey and Singh 2002; Zhai et al. 2013). Degeneration of the seminiferous tubules was found in rats at 7 mg molybdenum/kg/day as sodium molybdate, which was administered in the diet from weaning age through sexual maturity (Jeter and Davis 1954); although this study provided an adequate amount of copper, there was evidence of copper deficiency (achromotrichia) at ≥7 mg molybdenum/kg/day. Degeneration of the seminiferous tubules was also reported by Pandey and Singh (2002) for intermediate-duration (60 days) exposures in rats administered molybdenum at doses up to 24 mg molybdenum/kg/day (sodium molybdate); however, the dose(s) producing the effects are unclear and incidence data were not reported. Lyubimov et al. (2004) reported delayed spermiation, increased sperm and seminal fluid concentration, and increased sloughing of epididymal tail epithelial cells at 4.4 mg molybdenum/kg/day as ammonium tetrathiomolybdate. Although the basal diet in the Lyubimov et al. (2004) study provided 11 ppm of copper, which is above the NAS (1995) recommended amount for rats (5 ppm), dietary copper supplementation (110 ppm) prevented testicular toxicity. It is likely that the tetrathiomolybdate interfered with the absorption of dietary copper, resulting in a secondary effect of copper insufficiency. In contrast to these findings, Murray et al. (2013) did not find any alterations in spermatid, sperm counts, sperm motility, or sperm morphology in rats exposed to 60 mg molybdenum/kg/day as sodium molybdate in the diet. Although the study found no alterations in the percentage of motile sperm, a significant decrease in the percentage of progressively motile sperm was observed at 60 mg molybdenum/kg/day (59.0% compared to 69.4% in controls). The investigators noted that the decrease was likely attributable to the control group having a value that approached the upper end of the range for historical controls (mean of 59.8%). Given the results of the Lyubimov et al. (2004), Pandey and Singh (2002), and Zhai et al. (2013) studies, the 60 mg molybdenum/kg/day dose level was considered a LOAEL for male reproductive effects. It should be noted that the basal diet in this study exceeded the NAS (1995) recommendation; the copper content was 14.23 ppm.

Effects have also been observed in female laboratory animals. An increase in the rate of M II oocyte morphological abnormalities and decreases in relative ovarian weights were observed in mice exposed to 11 mg molybdenum/kg/day as sodium molybdate in drinking water for 14 days (Zhang et al. 2013). The investigators also reported ovarian hyperemia in mice exposed to 5.3 and 11 mg molybdenum/kg/day; however, the incidence and statistical significance were not reported. Irregularities in the estrous cycle were reported in rats administered 1.5 mg molybdenum/kg/day in the drinking water from weaning through sexual maturity (Fungwe et al. 1990). Murray et al. (2013) did not find any alterations in vaginal cytology or estrus cycle in female rats exposed to ≤60 mg molybdenum/kg/day as sodium molybdate and Bersenyi et al. (2008) did not find histological alterations in the ovaries of rabbits exposed to 1.2 mg molybdenum/kg/day as ammonium heptamolybdate in the diet for 14 days.

Several intermediate-duration studies evaluated fertility. No alterations in fertility were observed in female rats exposed to ≤15 mg molybdenum/kg/day as sodium molybdate in drinking water (Fungwe et al. 1990) or in male and female rats exposed to 7 mg molybdenum/kg/day as sodium molybdate in the diet when a high copper diet was administered (Jeter and Davis 1954). In contrast, Pandey and Singh (2002) reported decreases in fertility in males exposed to 14 mg molybdenum/kg/day and mated to unexposed females. Another study conducted by Jeter and Davis (1954) in which rats were exposed to 7 mg molybdenum/kg/day from weaning to maturity also found impaired male fertility; in this study, there is some indication that the diet did not provide an adequate level of copper.

3.2.2.6 Developmental Effects

There are limited data on the developmental effects of molybdenum in humans from two population studies. Vazquez-Salas et al. (2014) found an association between third trimester maternal urinary molybdenum levels (mean level of 54.0 μg/g creatinine) and infant psychomotor development indices, including gross and fine motor coordination, during the first 30 months of life in a study of women in Mexico participating in a prospective study of neurodevelopment in children. A doubling of creatinine corrected urinary molybdenum levels resulted in significant decreases in psychomotor development index scores. No association was found between maternal urinary molybdenum levels during pregnancy (mean levels ranged from 45.6 to 54.6 μg/g creatinine during the first, second, and third trimesters) and newborn body weight or infant mental development indices (sensory ability, memory, learning, problem solving, and verbal ability). Shirai et al. (2010) found no association between maternal urinary molybdenum levels and newborn body weight, length, or head circumference in women in Japan with mean urinary molybdenum levels of 79.0 μg/g creatinine. As noted elsewhere in this document, these observational epidemiology studies do not establish causality between molybdenum and developmental effects, and other factors are likely to have contributed to the risk.

Several studies have examined the effect of molybdenum on development in laboratory animals. No developmental effects were reported in three studies of rats exposed to molybdenum in the presence of adequate copper concentrations in the basal diet (Jeter and Davis 1954; Lyubimov et al. 2004; Murray et al. 2014). Murray et al. (2014) reported no effects on litter size, embryofetal survival, sex ratio, fetal body weight, or fetal malformations and variations in rats exposed to 38 mg molybdenum/kg/day as sodium molybdate in the diet on gestation days 6–20. Similarly, Lyubimov et al. (2004) found no effects on litter size or fetal survival in rats administered molybdenum daily via gavage at 4.4 mg molybdenum/kg/day as ammonium tetrathiomolybdate for 59–61 days (for 29 days prior to mating, during mating, and thereafter until sacrifice) in males or for 22–35 days (for 15 days prior to mating, during mating, and during gestation days 0–6) in females. No alterations in birth weights were observed in the offspring of male and female rats exposed to 7 mg molybdenum/kg/day as sodium molybdate for at least 14 weeks (Jeter and Davis 1954). However, a fourth study found decreases in the number of live fetuses, fetal crown-rump length, and fetal body weight in the offspring of male rats administered 14 mg molybdenum/kg as sodium molybdate via gavage for 60 days prior to mating to untreated females (Pandey and Singh 2002). The copper content of the commercial diet was not reported, but was assumed to be adequate. Two studies only available as abstracts provide additional information on the potential developmental toxicity of molybdenum. Lyubimov et al. (2002) found no developmental effects in rats exposed to 6 mg/kg/day as tetrathiomolybdate on gestation days 6–17. Exposure on gestation days 7–20, resulted in an increase in carpal/tarsal flexure in the offspring of dams exposed to 20 mg/kg/day ammonium tetrathiomolybdate (Lyubimov et al. 2003). Although neither study provided information on the copper content of the diet, it is assumed to be adequate based on Lyubimov et al. (2004).

Developmental effects have also been reported in studies in which the copper content of the diets were lower than the NAS recommended standard of 8 ppm for pregnant rats (NAS 1995). Fungwe et al. (1990) reported increases in fetal resorptions and decreases in litter weights in female rats exposed to 1.3 mg molybdenum/kg/day as sodium molybdate in the drinking water for 8 weeks prior to mating through gestation day 21; the copper content in the basal diet was 6.3 ppm. Decreased maternal body weight gain was also observed at doses resulting in developmental toxicity. Decreased weaning weights were observed in the offspring of rats exposed to ≥2 mg molybdenum/kg/day as sodium molybdate; the copper content of the diet was 5 ppm (Jeter and Davis 1954).

3.2.2.7 Cancer

No studies were located regarding cancer in humans and animals following oral exposure to molybdenum.

3.2.3 Dermal Exposure

3.2.3.1 Death

No studies were located regarding death in humans and animals following dermal exposure to molybdenum.

3.2.3.2 Systemic Effects

No studies were located regarding systemic effects in humans and animals following dermal exposure to molybdenum.

3.2.3.3 Immunological and Lymphoreticular Effects

There are limited data on the immunotoxicity of molybdenum in humans. Studies of patients with stainless steel stents (which contain nickel, chromate, and molybdenum) or in patients prior to hip or knee replacements found a low rate of positive results in patch tests with molybdenum (Koster et al. 2000; Menezes et al. 2004; Zeng et al. 2014). In patients with stainless steel stents, 3% had a positive delayed-type contact hypersensitivity reaction to molybdenum chloride (Koster et al. 2000). In the other studies, exposure to an unspecified molybdenum compound did not result in any positive hypersensitivity results.

Guinea pigs showed contact sensitization to a topical challenge with molybdenum pentachloride after induction via intradermal injection with 0.03% molybdenum and topical exposure to 5.2% molybdenum and an epicutaneous challenge with ≥0.35% molybdenum as molybdenum pentachloride (Boman et al. 1979). Similarly, guinea pigs were sensitized to 3.2% molybdenum as sodium molybdate following intradermal (3.2% molybdenum) or topical (8% molybdenum) induction (Boman et al. 1979).

3.2.3.4 Neurological Effects

No studies were located regarding neurological effects in humans and animals following dermal exposure to molybdenum.

3.2.3.5 Reproductive Effects

No studies were located regarding reproductive effects in humans and animals following dermal exposure to molybdenum.

3.2.3.6 Developmental Effects

No studies were located regarding developmental effects in humans and animals following dermal exposure to molybdenum.

3.2.3.7 Cancer

No studies were located regarding cancer in humans and animals following dermal exposure to molybdenum.

3.3 GENOTOXICITY

No studies were available regarding genotoxic effects of molybdenum compounds in humans following environmental or occupational exposure to these compounds. The genotoxicity of molybdenum compounds has been studied mostly in *in vitro* assays utilizing prokaryotic organisms and in mammalian cells. Limited information is available regarding the *in vivo* genotoxicity of molybdenum.

As shown in Table 3-3, sodium molybdate induced a modest, but statistically significant, increase in micronucleated bone marrow cells (polychromatic erythrocytes, PCE) from male C57BL/6J mice following two intraperitoneal injections of 200 or 400 mg/kg sodium molybdate on two consecutive days (Titenko-Holland et al. 1998). The increase in micronucleated cells per 1,000 PCE or in micronuclei per 1,000 PCE were about half of those produced by colchicine, the positive control. The same group of investigators reported that sodium molybdate induced a positive response in the dominant lethal assay in mice. In these experiments, male C57BL/6J mice were treated with 200 or 400 mg/kg sodium molybdate and were mated with non-treated female C3H/J mice at various times after dosing. Sodium molybdate

Table 3-3. Genotoxicity of Molybdenum Compounds *In Vivo*

Species	Compound	End point	Results	Reference
Mouse (male C57BL/6J)	Sodium molybdate	Micronuclei in bone marrow cells	(+)	Titenko-Holland et al. 1998
Mouse (male C57BL/6J)	Sodium molybdate	Dominant lethal assay	(+)	Titenko-Holland et al. 1998
Drosophila melanogaster wing spot test	Molybdenum chloride	Gene mutation	+	Ogawa et al. 1994

+ = positive result; (+) = weakly positive result did not significantly affect pregnancy rate, but induced a significant dose-related increase in post-implantation loss, which was attributed to an effect on post-meiotic male germ cells.

Assessment of the activity of molybdenum chloride in the *Drosophila melanogaster* wing spot test showed that the compound induced spots with one or two mutant hairs (small spots) (Ogawa et al. 1994). Almost all of the spots detected were mutant clones expressing the *mwh* phenotype which, according to the investigators, suggested a nonlethal genetic change such as gene mutation or mitotic recombination occurring at a late developmental stage, or a semi-lethal change such as partial aneuploidy for a chromosomal region containing the *mwh* locus.

Table 3-4 summarizes studies of genotoxic effects of molybdenum compounds in *in vitro* systems. Results of gene mutation and DNA tests performed in prokaryotic organisms, almost all conducted without metabolic activation, were mixed, but negative results outnumbered positive results. It is worth noting the positive results reported for potassium molybdate and ammonium molybdate in the DNA repair assay (Nishioka 1975). The investigator speculated that because molybdenum has a valence of +6 in both compounds, molybdate is an oxidizing agent and the positive effect might reflect an oxidation capacity.

The few studies that tested molybdenum compounds in mammalian cells provided mixed results (Table 3-4). Different results were reported by NTP (1997) and Gibson et al. (1997) in experiments with molybdenum trioxide: negative in the former study for chromosomal aberrations, and positive in the latter for micronuclei formation. Aside from the differences in end point tested, it should be noted that NTP (1997) tested concentrations of molybdenum trioxide of up to 10 µg/mL, whereas Gibson et al. (1997) tested concentrations of molybdenum trioxide ranging from 250 to 750 µg/mL. Titenko-Holland et al. (1998) reported positive results for micronuclei formation in human peripheral lymphocytes incubated with sodium or ammonium molybdate. However, because blood was collected from only two donors, the results should be interpreted with caution.

In summary, the limited information regarding effects *in vivo* of molybdenum compounds is insufficient to infer possible outcomes of exposure in human populations. *In vitro* studies in prokaryotic organisms provided mixed results, but there is suggestive evidence that molybdenum valence +6, as in molybdate compounds (MoO_4^{-2}), could induce genotoxicity due to its oxidative capacity. Too few studies were available regarding effects of molybdenum compounds in mammalian cells *in vitro* to draw a meaningful

Table 3-4. Genotoxicity of Molybdenum Compounds *In Vitro*

			Results		
Species (test system)	Compound	End point	With activation	Without activation	Reference
Prokaryotic organisms:					
Salmonella typhimurium, TA98, TA100, TA1535, TA1537, 1538	Ammonium molybdate	Gene mutation	No data	–	Arlauskas et al. 1985
S. typhimurium, TA97, TA98, TA100, TA 1535, TA1537	Molybdenum trioxide	Gene mutation	–	–	NTP 1997; Zeiger et al. 1992
Saccharmyces cerevistiae D3	Sodium molybdate	Gene conversion and mutation	No data	–	Singh 1983
Escherichia coli, WP2uvrA$^-$	Ammonium molybdate	Reverse gene mutation	No data	–	Arlauskas et al. 1985
E. coli, 2 WP2 strains	Ammonium molybdate	Reverse gene mutation	No data	+	Nishioka 1975
E. coli, CM571	Ammonium molybdate	Reverse gene mutation	No data	–	Nishioka 1975
E. coli PQ37	Molybdenum chloride	DNA damage	No data	–	Olivier and Marzin 1987
E. coli WP2$_s$(λ)	Sodium molybdate	DNA damage	No data	(+)	Rossman et al. 1984
E. coli WP2$_s$(λ)	Sodium molybdate	DNA damage	No data	(+)	Rossman et al. 1991
Bacillus subtilis, H17 and M45	Molybdic acid	DNA repair assay	No data	–	Kanematsu et al. 1980
B. subtilis H17 and M45	Molybdenum disulfide	DNA repair assay	No data	–	Kanematsu et al. 1980
B. subtilis H17 and M45	Molybdenum chloride	DNA repair assay	No data	–	Nishioka 1975
B. subtilis H17 and M45	Potassium molybdate	DNA repair assay	No data	+	Nishioka 1975
B. subtilis H17 and M45	Ammonium molybdate	DNA repair assay	No data	+	Nishioka 1975
Photobacterium fischeri	Sodium molybdate	Direct mutation	No data	–	Ulitzur and Barak 1988
Mammalian cells:					
Human peripheral lymphocytes	Sodium molybdate	Micronucleus assay	No data	(+)	Titenko-Holland et al. 1998
Human peripheral lymphocytes	Ammonium molybdate	Micronucleus assay	No data	+	Titenko-Holland et al. 1998

Table 3-4. Genotoxicity of Molybdenum Compounds *In Vitro*

			Results		
Species (test system)	Compound	End point	With activation	Without activation	Reference
Syrian hamster embryo (SHE) cells	Molybdenum trioxide	Micronucleus assay	No data	+	Gibson et al. 1997
Chinese hamster ovary (CHO) cells	Molybdenum trioxide	Chromosomal aberrations	–	–	NTP 1997
CHO cells	Molybdenum trioxide	Sister chromatid exchanges	–	–	NTP 1997

+ = positive result; (+) = weakly positive result; – = negative result; ± = equivocal result conclusion, although two studies found positive results and a third study found weak positive results in the micronuclei assay.

3.4 TOXICOKINETICS

3.4.1 Absorption

3.4.1.1 Inhalation Exposure

Inhaled molybdenum particles that deposit in the respiratory tract are subject to three general distribution processes: (1) bronchial and tracheal mucociliary transport to the gastrointestinal tract; (2) transport to thoracic lymph nodes (e.g., lung, tracheobronchial, mediastinal); or (3) absorption into blood and/or lymph and transfer to other tissues (e.g., peripheral lymph tissues, liver, kidney). The above processes apply to all forms of deposited molybdenum, although the relative contributions of each pathway and rates associated with each pathway vary with the physical characteristics (e.g., particle size, solubility). Particles having diameters >5 µm are deposited primarily in the upper airways (extrathoracic, tracheobronchial regions) and are cleared from the respiratory tract primarily by mucociliary transport to the gastrointestinal tract (Bailey et al. 2007; ICRP 1994). Smaller particles (≤5 µm) are deposited primarily in the pulmonary region (terminal bronchioles and alveoli). Particles are cleared from the pulmonary region primarily by absorption, lymph drainage, macrophage phagocytosis and migration, and upward mucociliary flow.

Dissolved molybdenum is absorbed into blood. The rate of absorption will depend on solubility. ICRP (2012) assigns molybdenum sulfide, oxides, and hydroxides to a “slow” classification in their absorption, which equates to an expected terminal absorption half-time of approximately 19 years (Baily et al. 2007; ICRP 1994). More soluble forms of molybdenum, such as molybdenum trioxide ($Mo^{VI}O_3$), would be expected to undergo more rapid dissolution and absorption.

Quantitative estimates of absorption following inhalation exposure to molybdenum in humans or animals were not identified. Evidence for absorption of molybdenum trioxide is available from inhalation studies on molybdenum trioxide conducted in rodents (Fairhall et al. 1945; NTP 1997). Fairhall et al. (1945) showed distribution to several tissues following inhalation exposure of guinea pigs to molybdenum trioxide. In rats and mice exposed to inhaled molybdenum trioxide (6.7–67 mg molybdenum/m^3, 6 hours/day, 5 days/week for 2 years), exposure-dependent increases in blood molybdenum were observed (NTP 1997). The respectively blood molybdenum levels in the 0, 6.7, 20, and 67 mg molybdenum/m^3 groups were 0.221, 0.800, 1.774, and 6.036 μg/g in male rats, 0.059, 0.355, 0.655, and 2.411 μg/g in female rats, 0.102, 0.208, and 0.770 μg/g in male mice (no data were available for controls), and 0.043, 0.066, 0.198, and 0.523 μg/g for female mice.

3.4.1.2 Oral Exposure

Absorption of ingested molybdenum has been studied in human adults and infants (Cantone et al. 1993, 1997; Engle et al. 1967; Giussani et al. 1998, 2006, 2007; Novotny and Turnlund 2006, 2007; Robinson et al. 1993; Sievers et al. 2001a, 2001b; Turnlund et al. 1995a, 1995b; Werner et al. 1998; Yoshida et al. 2006). These studies fall into two general categories: mass balance studies and bioavailability studies. Mass balance studies estimate the absorption fraction from measurements of the difference between the ingested dose of molybdenum and fecal excretion (the difference being net absorption). Bioavailability studies estimate the absorption fraction from measurements of the plasma concentration of molybdenum following the oral dose. These methods provide estimates of net absorption in that absorbed molybdenum that is excreted into the gastrointestinal tract (e.g., biliary excretion) may not be accurately quantified from mass balance or bioavailability estimates. However, both approaches have been facilitated by the use of stable isotopes of molybdenum (^{95}Mo, ^{96}Mo), which allow measurement of plasma and excretion kinetics following concurrent intravenous and oral dosing. The use of stable isotopes also allows measurement of the administered molybdenum in plasma and excreta, distinct from background sources of molybdenum derived from other sources and preexisting body stores. By incorporating elimination kinetics data into mathematical models that include parameters representing absorption and fecal excretion of absorbed molybdenum, the absorption fraction can be estimated. In most reported stable isotope studies, the exact form of molybdenum administered was not reported. However, typically, the isotope dosing material was prepared from an acid dissolution of metallic molybdenum ($Mo^{[0]}$). The resulting material dissolved in water most likely was a mixture of soluble molybdate anion ($Mo^{[VI]}O_4^{2-}$) and other soluble molybdenum oxide hydrates.

Balance and bioavailability studies conducted in humans have shown that the fraction of ingested molybdenum that is absorbed depends on numerous factors, including molybdenum dose level, fasting, diet, and nutritional status. Absorption was estimated to be 80–100% in replete fasted adults who ingested molybdenum dissolved in water or in a beverage (Giussani et al. 2006; Novotny and Turnlund 2006, 2007; Turnlund et al. 1995a). Absorption was 80–100% following a single dose of 20–40 μg Mo/kg dissolved in water and decreased with increasing dose level; absorption was 60% after a dose of 60 μg Mo/kg (Giussani et al. 2006). Absorption was lower when molybdenum was ingested with a meal

(40–60%), when dissolved in black tea (20%), or when incorporated into vegetables cultivated with ^{96}Mo (30–60%), compared to when ingested without a meal (80–100%) (Giussani et al. 2006; Werner et al. 1998). Absorption was lower when molybdenum was incorporated into the diet (83%) compared to when it was administered in a beverage (90–94%) (Novotny and Turnlund 2007). Absorption appears to be affected by dietary molybdenum intake and molybdenum nutritional status. The absorption fraction was 90% in adults fed a diet containing 22 μg/day (approximately 0.3 μg Mo/kg/day), compared to 94% when fed a diet containing 467 μg Mo/day (approximately 7 μg Mo/kg/day) (Novotny and Turnlund 2007). Absorption in infants (gestational age 30–39 weeks) was 96–99% when a stable isotope of molybdenum was mixed with breast milk or infant formula (Sievers et al. 2001a, 2001b).

Long-term diet mass balance studies, without the aid of stable isotopes, have been conducted in adults and children (Engel et al. 1967; Robinson et al. 1973; Tipton et al. 1966). Because these studies cannot distinguish between the ingested dose of molybdenum and molybdenum excreted from body stores, these studies will underestimate the absorption fraction. A 50-week balance study conducted in two adult males (age 23 and 25 years) found absorption to range from 60 to 80% (Tipton et al. 1966). A 3-week balance study conducted in women (age 19–21 years) found absorption to range from 40 to 70% (Robinson et al. 1973). An 8-day balance study conducted in women (age 18–23 years) found absorption to range from 72 to 84% (Yoshida et al. 2006). Balance studies (18–30 days) conducted in female children (age 6–10 years) estimated the absorption fraction from diet to range from 67 to 85% (Engel et al. 1967).

Measurements of the time course of plasma molybdenum following oral doses of molybdenum indicate that absorption is relatively rapid, with peak concentrations in plasma attained within 100 minutes of dosing (Giusanni et al. 2006; Novotny and Turnlund 2007).

Studies of absorption and elimination kinetics conducted in swine provide estimates of absorption of ingested molybdenum. Based on cumulative urinary and fecal excretion measurements in swine dosed with a stable isotope of molybdenum, absorption was estimated to be between 80 and 90% (Bell et al. 1964). Studies conducted in rats have shown that tetrathiomolybdate ($Mo^{VI}S_4^{2-}$) is more poorly absorbed when ingested in the diet; approximately 21% was absorbed when the copper content of the diet was 8 ppm (Mills et al. 1981b).

3.4.1.3 Dermal Exposure

Studies evaluating the absorption of molybdenum following dermal exposure were not identified.

3.4.2 Distribution

3.4.2.1 Inhalation Exposure

Very little information on the distribution on molybdenum following inhalation exposure is available. Following exposure of guinea pigs to inhaled molybdenum trioxide (150–300 mg/m^3, 1 hour/day, 5 days/week for 5 weeks), molybdenum was distributed to the lungs, liver, kidneys, and bone (Fairhall et al. 1945). Tissue levels decreased by approximately 20% in the 2-week postexposure period.

3.4.2.2 Oral Exposure

Absorbed molybdenum distributes to various tissues. Human autopsy studies have found that the kidney and liver have the highest amounts of molybdenum (Iyengar et al. 1978; Schroeder et al. 1970; Sorensen and Archambault, 1963; Sumino et al. 1975; Tipton and Cook 1963; Tipton et al. 1965; Yoo et al. 2002; Zeisler et al. 1988). Based on a review of these data, Giussani (2008) estimated liver and kidney molybdenum concentrations to be approximately 0.5–1.5 µg Mo/g wet in liver (700–2,700 µg) and 0.2–0.4 µg Mo/g wet in kidney (55–120 µg). Coughtrey and Thorne (1983) reported relatively high concentrations (56 µg Mo/g) in bone, based on their recalculation of measurements of molybdenum in bone ash reported in Nusbaum et al. (1965) and Iyengar et al. (1978). However, these results are not supported by other studies (previously cited) and have been attributed to overestimation of tissue concentrations measured by arc emission spectrometry in the Nusbaum et al. (1965) and Iyengar et al. (1978) studies (Giussani 2008).

Results of studies in rats and guinea pigs exposed to oral molybdenum show that molybdenum is widely distributed (Bibr et al. 1977; Howell et al. 1993; Murray et al. 2014; Pandey et al. 2002). Generally, the highest molybdenum tissue concentration is observed in the kidney. Molybdenum also is distributed to liver, spleen, brain, lung, heart, bone, muscle, testis, epididymis, seminal vesicles, prostate, blood cells, and plasma. Studies conducted in rats have shown that molybdenum absorbed following ingestion of tetrathiomolybdate from the diet distributes to the kidneys and liver (Mills et al. 1981a).

Maternal-Fetal Transfer. Results of studies in humans and animals show that molybdenum is distributed to the fetus. In humans, maternal and fetal cord blood levels obtained from 33 maternal-fetal pairs at parturition show similar molybdenum levels (maternal: 1.44±0.75 μg/L, mean±standard deviation [SD]; fetal: 1.44±0.89 μg/L) (Bougle et al. 1989). Molybdenum concentrations in venous cord blood (flowing from the placenta to the fetus; 0.7±0.2 μg/L, mean±SD) were slightly higher than in arterial cord blood (flowing from the fetus to the placenta; 0.6±0.2 μg/L), indicating fetal retention of molybdenum (Krachler et al. 1999).

Gestational exposure of rats to ammonium molybdate and thiomolybdate shows distribution of molybdenum to fetal liver, kidney, bone, and brain (Howell et al. 1993). Levels in liver, kidney, and bone were similar, with lower levels in brain. In rats, dose-dependent increases in placental and maternal liver content of molybdenum were observed following gestational exposure to molybdenum (sodium molybdate) in drinking water (5–100 mg Mo/L; equivalent to approximately 0.76–15 mg/kg/day, based on intermediate exposure to nonpregnant female rats) over the full dose range (Fungwe et al. 1989). However, neonatal whole-body levels of molybdenum reached a plateau at drinking water concentrations ≥50 mg/L (Fungwe et al. 1989). Results suggest that molybdenum levels in the fetus reach steady state more rapidly than in dams.

Maternal-Infant Transfer. Several studies have measured molybdenum in breast milk (Anderson 1992; Aquilio et al. 1996; Biego et al. 1998; Bougle et al. 1988; Casey and Neville 1987; Dang et al. 1984; Friel et al. 1999; Krachler et al. 1998; Wappelhorst et al. 2002); the mean concentrations ranged from 0.02 to 24 μg/L. Breast milk concentrations are highest at the start of breast feeding and then decline (EFSA 2013). In the only study comparing maternal intake to breast milk levels, Wappelhorst et al. (2002) did not find a correlation between breast milk concentrations of molybdenum (mean concentration of 72 μg/L) and maternal molybdenum intake (mean intake of 132 μg/day).

3.4.2.3 Dermal Exposure

Studies evaluating the distribution of molybdenum following dermal exposure were not identified.

3.4.3 Metabolism

Molybdenum exists in several valence states and may undergo oxidation and reduction. Although molybdenum can exist in biological systems in several different valence states (3+, 4+, 5+, and 6+), the primary form of molybdenum that interacts with enzyme systems is $Mo^{[VI]}$, as the molybdate anion

($Mo^{[VI]}O_2^{2-}$) (Nakanishi et al. 2013). After molybdate is taken into a cell, it is incorporated into a molybdopterin to form molybdenum cofactor (Moco). Moco is a sulfur-molybdate complex that forms the prosthetic group in molybdenum-dependent enzymes (Mendel and Kruse 2012; Schwarz et al. 2009). Given that Moco is extremely sensitive to oxidation, it is believed that it is bound to a Moco binding protein in the cell (Mendel and Kruse 2012). This stored Moco would be readily available to meet the cell's demand for molybdenum enzymes. Molybdate forms complexes with copper and binds to plasma proteins as a copper-molybdenum-sulfur (Cu-Mo-S) complex (Nederbragt 1980, 1982).

3.4.4 Elimination and Excretion

3.4.4.1 Inhalation Exposure

Studies investigating the elimination and excretion of molybdenum following inhalation exposure were not identified.

3.4.4.2 Oral Exposure

Absorbed molybdenum is excreted in urine and feces in humans. Urine is the dominant excretion route, accounting for approximately 75–90% of the absorbed dose (Giussani 2008; Novotny and Turnlund 2007). The fraction excreted in urine increases with increasing dietary intake (Novotny and Turnlund 2007). Urine also is the dominant excretory route for absorbed molybdenum in swine. Following an oral dose, approximately 90% of the dose was excreted in urine (Bell et al. 1964). To measure urinary and fecal excretion of molybdenum, Turnlund et al (1995a, 1995b) exposed four healthy adult males to various doses of a radioactive isotope of molybdenum (24–1,378 μg ^{100}Mo/day) and administered intravenous doses of stable isotope of molybdenum (33 μg ^{97}Mo). Six days after exposure to ^{100}Mo in the diet, 17.8% of the ^{100}Mo label was excreted in the urine at the lowest dose tested (total molybdenum dose of 24 μg/day). As the molybdenum dose increased, the amount excreted in the urine also increased; at the highest dose (1488 μg/day), 82.1% of the ^{100}Mo was excreted in the urine. A similar pattern of urinary excretion was found when ^{97}Mo was measured: 32.7% of the label at 24 μg/day and 86.7% at 1,488 μg/day. The percentage of the molybdenum dose excreted in the feces decreased with increasing doses. At the lowest dose tested, 9.4% of the ^{100}Mo dose was excreted in the feces; at the highest dose, 7.5% of the ^{100}Mo dose was excreted in the feces. In contrast, no consistent pattern of fecal ^{97}Mo excretion was found. When total molybdenum excretion was measured, the study found that 41% was excreted in feces and 59% was excreted in urine at the lowest dose tested and 6% was excreted in feces and 94% was excreted in urine at the highest dose tested. Fecal excretion of absorbed molybdenum is thought to result from biliary secretion. Studies conducted in rats have shown that, following an intravenous dose of $Mo^{[V]}$ or $Mo^{[VI]}$, approximately 1% of the molybdenum dose was secreted into bile in a period of 4 hours (Lener and Bibr 1979).

The rate of elimination of molybdenum from plasma has been studied in human clinical studies (Cantone et al. 1997; Rosoff and Spencer 1964; Thompson et al. 1996; Werner et al. 2000). Elimination is approximately biphasic, with mean half-times of 30 minutes and 6.6 hours (Giussani 2008).

The whole-body elimination rate in rats is dose-dependent (Bibr and Lener 1973). Following oral administration of $Mo^{[VI]}$ at doses <3 μg Mo/kg, elimination was mono-phasic with a half-time of approximately 47 hours. Following doses >3 μg Mo/kg, the rate of elimination increased, with an increasing proportion of elimination contributed by a fast phase having a half-time of 6 hours.

3.4.4.3 Dermal Exposure

Studies evaluating the elimination and excretion of molybdenum following dermal exposure were not identified.

3.4.5 Physiologically Based Pharmacokinetic (PBPK)/Pharmacodynamic (PD) Models

Physiologically based pharmacokinetic (PBPK) models use mathematical descriptions of the uptake and disposition of chemical substances to quantitatively describe the relationships among critical biological processes (Krishnan et al. 1994). PBPK models are also called biologically based tissue dosimetry models. PBPK models are increasingly used in risk assessments, primarily to predict the concentration of potentially toxic moieties of a chemical that will be delivered to any given target tissue following various combinations of route, dose level, and test species (Clewell and Andersen 1985). Physiologically based pharmacodynamic (PBPD) models use mathematical descriptions of the dose-response function to quantitatively describe the relationship between target tissue dose and toxic end points.

PBPK/PD models refine our understanding of complex quantitative dose behaviors by helping to delineate and characterize the relationships between: (1) the external/exposure concentration and target tissue dose of the toxic moiety, and (2) the target tissue dose and observed responses (Andersen and Krishnan 1994; Andersen et al. 1987). These models are biologically and mechanistically based and can be used to extrapolate the pharmacokinetic behavior of chemical substances from high to low dose, from route to route, between species, and between subpopulations within a species. The biological basis of

PBPK models results in more meaningful extrapolations than those generated with the more conventional use of uncertainty factors.

The PBPK model for a chemical substance is developed in four interconnected steps: (1) model representation, (2) model parameterization, (3) model simulation, and (4) model validation (Krishnan and Andersen 1994). In the early 1990s, validated PBPK models were developed for a number of toxicologically important chemical substances, both volatile and nonvolatile (Krishnan and Andersen 1994; Leung 1993). PBPK models for a particular substance require estimates of the chemical substance-specific physicochemical parameters, and species-specific physiological and biological parameters. The numerical estimates of these model parameters are incorporated within a set of differential and algebraic equations that describe the pharmacokinetic processes. Solving these differential and algebraic equations provides the predictions of tissue dose. Computers then provide process simulations based on these solutions.

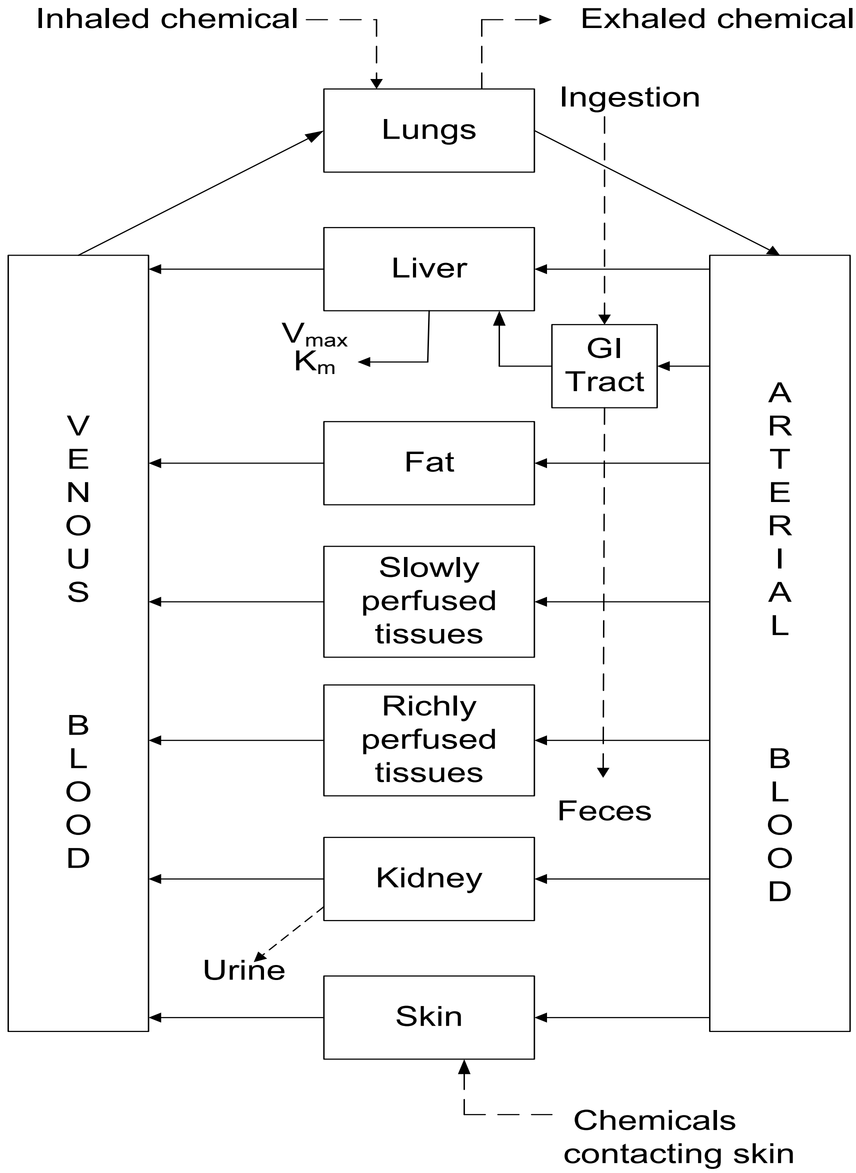
The structure and mathematical expressions used in PBPK models significantly simplify the true complexities of biological systems. However, if the uptake and disposition of the chemical substance(s) are adequately described, this simplification is desirable because data are often unavailable for many biological processes. A simplified scheme reduces the magnitude of cumulative uncertainty. The adequacy of the model is, therefore, of great importance, and model validation is essential to the use of PBPK models in risk assessment.

PBPK models improve the pharmacokinetic extrapolations used in risk assessments that identify the maximal (i.e., the safe) levels for human exposure to chemical substances (Andersen and Krishnan 1994). PBPK models provide a scientifically sound means to predict the target tissue dose of chemicals in humans who are exposed to environmental levels (for example, levels that might occur at hazardous waste sites) based on the results of studies where doses were higher or were administered in different species. Figure 3-3 shows a conceptualized representation of a PBPK model.

If PBPK models for molybdenum exist, the overall results and individual models are discussed in this section in terms of their use in risk assessment, tissue dosimetry, and dose, route, and species extrapolations.

Several multi-compartmental models of the kinetics of molybdenum in humans have been developed (Giussani 2008; Giussani et al. 1998, 2000; Novotny and Turnlund 2007; Thompson et al. 1996). The

Figure 3-3. Conceptual Representation of a Physiologically Based Pharmacokinetic (PBPK) Model for a Hypothetical Chemical Substance



Note: This is a conceptual representation of a physiologically based pharmacokinetic (PBPK) model for a hypothetical chemical substance. The chemical substance is shown to be absorbed via the skin, by inhalation, or by ingestion, metabolized in the liver, and excreted in the urine or by exhalation.

Source: Krishnan and Andersen 1994

latest of these are the Giussani (2008) and Novotny and Turnlund (2007) models. Both models yield similar predictions when applied to the same dosing scenarios (Giusanni 2008). The Giussani (2008) model has been adopted for use by the International Commission on Radiological Protection (ICRP) and is described in this section.

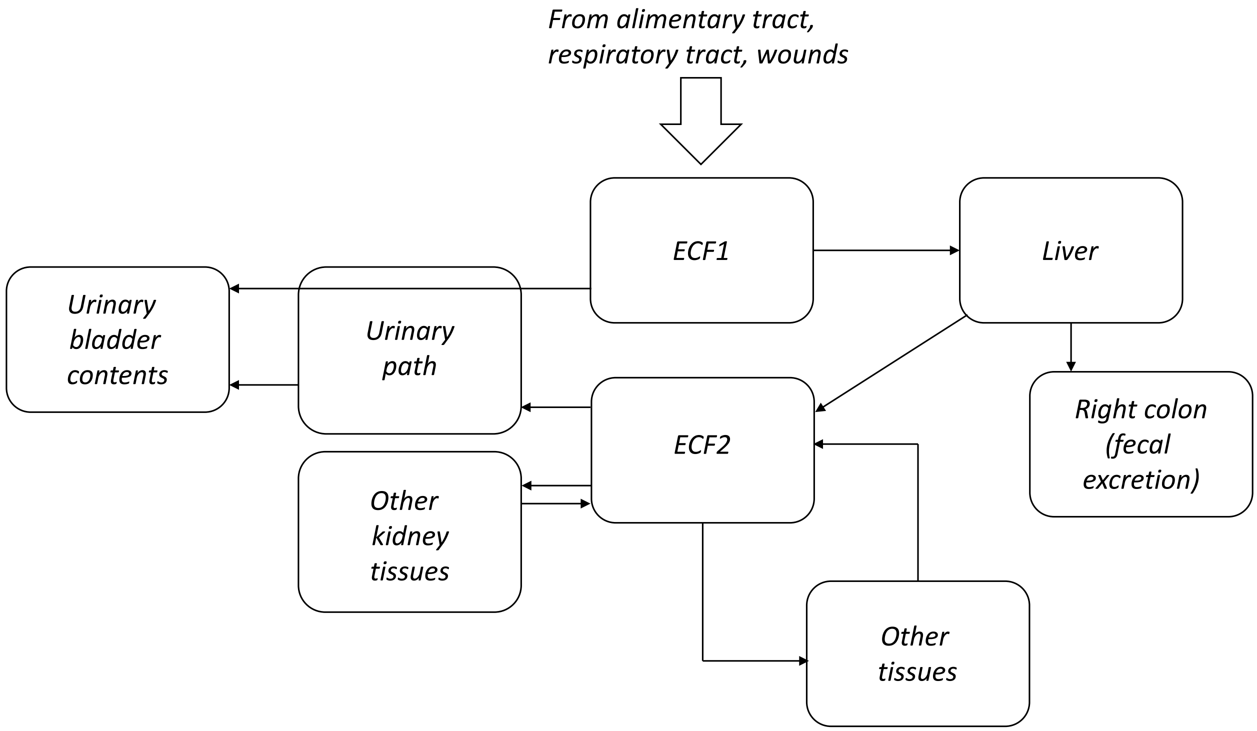
Giussani (2008) Model.

Giussani (2008) developed a model of molybdenum kinetics in humans. The structure of the model is shown in Figure 3-4 and parameter values are presented in Table 3-5. Data used to derive and evaluate the model are described in Giusanni (2008) and included human clinical studies in which subjects were administered intravenous or oral doses of stable isotopes of molybdenum (Giusanni et al. 2006, 2007; Novotny and Turnlund 2006, 2007; Turnlund et al. 1995a; Werner et al. 1998, 2000). The Giussani (2008) model has been adopted for use by the ICRP and is described in this section.

The model consists of two central compartments representing extracellular fluids (ECF) and compartments representing liver, kidney (two subcompartments), and a lumped compartment representing all other tissues. All transfers of molybdenum between compartments are first order and governed by first-order rate coefficients (day^{-1}). The two ECF compartments represent fast and slow transfer pathways out of the ECF and were based on studies conducted in humans, which provide evidence for multi-phasic clearance of molybdenum from plasma (Giussani et al. 2007; Werner et al. 2000). The half-times for the two ECF compartments are approximately 30 minutes for ECF1 and 280 minutes for ECF2. Transfers from the fast compartment (ECF1) are to liver, kidney, and urine. Transfers from the slow compartment (ECF2) are to urine, kidney, and other tissues; the slow compartment also receives molybdenum from the liver. Retention half-times in tissues are 41 days for liver, 14.5 days for kidney, and 21.5 days for the other tissue compartment. Excretion of absorbed molybdenum occurs in urine (88%) and transfer from liver to the gastrointestinal tract (12%).

The model can simulate absorption from the gastrointestinal tract and respiratory tract. The absorption fraction for the gastrointestinal pathway uses an absorption fraction of 0.9 for molybdenum ingested in liquids and 0.6 for molybdenum ingested in the diet. The model predicts a steady state for constant dietary intake of molybdenum in adults, in which approximately 52% of the molybdenum body burden is in liver, 3% is in kidney, 45% is in other tissues, 53% of the daily dose is excreted in urine, and 47% of the daily dose is excreted in feces (Giussani 2008). The model is constructed to be able to interface with output from the ICRP Human Respiratory Tract Model (HRTM) (ICRP 1994; Baily et al. 2007). The

Figure 3-4. The Proposed Systemic Model for Molybdenum Radionuclides



ECF = extracellular fluid

Source: Reprinted from Giussani (2008) with permission from Elsevier.

Table 3-5. Transfer Rates (Day^{-1}) for the Molybdenum Model

Transfer rate	Value (day^{-1})
ECF1 to ECF2	12.5
ECF1 to liver	14.2
ECF1 to urinary bladder contents	6.5
ECF2 to urinary path	1.7
ECF2 to other kidney tissues	0.115
ECF2 to other tissues	1.73
Liver to alimentary tract	0.0048
Liver to ECF2	0.0122
Other kidney tissues to ECF2	0.0474
Other tissues to ECF2	0.0323
Urinary path to urinary bladder contents	1.40
Urinary bladder contents to urine	12
Modified parameters of the alimentary tract	
Stomach to small intestine (liquid form)	100
Stomach to small intestine (diet)	40
Small intestine to right colon (liquid form)	10
Small intestine to right colon (diet)	16
f_A (liquid form)[a]	0.9
f_A (diet)[a]	0.6

[a]Dimensionless number.

ECF = extracellular fluid

Source: Reprinted from Giussani (2008) with permission from Elsevier.

inputs to the Giussani (2008) model from the HRTM would be simulated transfers of molybdenum to the gastrointestinal tract (mucociliary transfer) and to blood (absorption from the respiratory tract), depending on the particle size and solubility of the inhaled molybdenum, and other physiological factors (e.g., age, activity).

Novotny and Turnlund (2007) Model.

The major difference between the structures of the Giussani (2008) and Novotny and Turnlund (2007) models is that the Novotny and Turnlund (2007) model has a single lumped compartment representing all tissues outside of the vasculature. The Novotny and Turnlund (2007) model has two configurations: an intravenous configuration, which has two plasma compartments, representing fast and slower clearance, and an oral configuration, which has a single plasma compartment. Molybdenum exchanges between plasma and a lumped tissue compartment. Urinary excretion is represented as a direct transfer from plasma. Absorbed molybdenum is also transferred to the gastrointestinal tract.

Novotny and Turnlund (2006, 2007) conducted mass balance studies with subjects who ingested stable isotopes of molybdenum in the context of varying dietary intakes of molybdenum (22–1,490 μg Mo/day) and found that certain model parameters were dependent on dietary intake. These included, in association with increasing dietary intake, an increase in the first-order rate coefficients for gastrointestinal absorption, and urinary excretion, and a decrease in the rate coefficients for transfer from plasma to tissues. The largest adjustments were needed to simulate molybdenum kinetics in subjects who consumed >121 μg Mo/day and included a 70% decrease in the coefficient for transfer of molybdenum from plasma to tissues and a 660% increase in the rate coefficient for transfer from plasma to urine. These results suggest that high molybdenum intakes (>121 μg Mo/day) result in physiological adaptations that increase excretion of absorbed molybdenum (Novotny and Turnlund 2007).

3.5 MECHANISMS OF ACTION

3.5.1 Pharmacokinetic Mechanisms

Absorption. Mechanisms that participate in absorptive transport of molybdenum in the gastrointestinal tract have not been characterized. Molybdate (MoO_4^{2-}) and sulfate (SO_4^{2-}) show mutually competitive inhibition for absorptive transport in rat small intestine, suggesting involvement of a common transporter for both anions (Cardin and Mason 1975, 1976). This transporter may be the Na^+/SO_4^{2-} symporter (NaS1 or SLC13A1) expressed in rodent small intestine and renal proximal tubule (Markovich and Aronson 2007; Murer et al. 1994). In humans, NaS1 is expressed in kidney but not small intestine, suggesting that mechanisms of absorptive transport in humans may be different from that of rodents (Lee at al. 2000).

Distribution. Bacteria and eukaryotes express cell membrane molybdate transporters, one of which (MoT_2) also appears to be expressed in humans (Tejada-Jimenez et al. 2007, 2011). In eukaryotes, this transporter participates in the delivery of molybdate into cells for incorporation into molybdopterin-cofactor (Moco), the biologically active prosthetic group in molybdenum-dependent enzymes (Schwarz et al. 2009). MoT_2 transport of molybdate is inhibited by sulfate, suggesting a common carrier for molybdate and sulfate. A sulfate-insensitive oxalate-sensitive molybdate transporter has been described in mammalian MEK-293T cells grown in culture (Nakanishi et al. 2013). Uptake of molybdate into human red blood cells involves participation of the Cl^{-1}/HCO_3^{-1} anion exchanger (Gimenez et al. 1993).

Metabolism. Molybdenum-dependent enzymes contain a molybdopterin cofactor (Moco), which is formed in a series of enzymatically catalyzed steps (Mendel and Bittner 2006). The final step, insertion of molybdate into Moco, may involve displacement of copper from of the molybdate binding site, which may provide a mechanism for copper-molybdenum interactions in regulating Moco synthesis and copper-induced deficiency in molybdenum-dependent enzymes (Mendel and Bittner 2006). Binding of molybdenum to plasma proteins involves formation of a Cu-Mo-S complex (Nederbragt 1980, 1982).

Excretion. Mechanisms that participate in the renal excretion of molybdenum have not been characterized. In sheep, reabsorption of filtered molybdate (MoO_4^{2-}) is saturable, which results in an increase in the fraction of filtered molybdate excreted as the plasma molybdate concentration increases and approaches or exceeds the tubular maximum (Ryan et al. 1987). In sheep and rat kidney, sodium-dependent reabsorptive transport of molybdate (MoO_4^{2-}) and sulfate (SO_4^{-2}) exhibit mutual inhibition (Ryan et al. 1987). This is consistent with participation of the Na^+/SO_4^{2-} symporter (NaS1 or SLC13A1) in the reabsorption of molybdate. This symporter is also expressed in the human renal proximal tubule (Markovich and Aronson 2007; Murer et al. 1994).

3.5.2 Mechanisms of Toxicity

The mechanism of molybdenum toxicity has not been well-established. There are some indications that the mode of action may involve altered copper utilization; however, it is likely that other mechanisms, including direct molybdenum alterations, are involved. Support of the mode of action involving impaired copper utilization comes from toxicology studies demonstrating more severe effects when animals are maintained on a copper-deficient diet; molybdenum induced alterations in copper levels in the plasma, liver, and kidneys; and apparent reversal of adverse effects following administration of high doses of copper. A number of the effects observed in animals orally exposed to molybdenum, particularly decreases in body weight and anemia (Arrington and Davis 1953; Brinkman and Miller 1961; Franke and Moxon 1937; Gray and Daniel 1954; Johnson et al. 1969), are similar to those observed in copper-deficient animals. Administration of high levels of copper results in a fairly rapid improvement or prevents the effect from occurring (Arrington and Davis 1953; Lyubimov et al. 2004). In rats fed a copper-adequate diet, exposure to high levels of molybdenum in the diet resulted in significant increases in plasma copper levels (Nederbragt 1980, 1982), most of which were in a “tightly bound form” that did not appear to be associated with ceruloplasmin (major copper-carrying protein in the blood), as evidenced by the lack of an increase in ceruloplasmin levels (Nederbragt 1980). Significant increases in liver and kidney copper levels were also observed in rats exposed to molybdenum in the diet and maintained on a copper-adequate diet.

In ruminants, which appear to be very sensitive to molybdenum toxicity, it is believed that molybdenum reacts with sulfate generated in the rumen to form thiomolybdates; copper can bind to these thiomolybdates, which impairs its absorption. There is also some indication that cupric thiomolybdates can form in the blood if dietary copper levels are inadequate (Telfer et al. 2004). The copper in these cupric thiomolybdates is unavailable to ceruloplasmin and other copper-containing proteins, resulting in a functional copper deficiency (Vyskocil and Viau 1999). In monogastric animals exposed to sodium molybdate, administration of sulfate decreases the toxicity of molybdenum (Miller et al. 1956; Van Reen 1959). However, when rats were fed diets containing molybdate and sulfide, there was a substantial increase in plasma molybdenum and copper levels and liver molybdenum levels and a decrease in ceruloplasmin activity. In the plasma, there was a shift in the fraction of copper associated with albumin and ceruloplasmin (Mills et al. 1981a). Similar findings were observed in rats administered tetrathiomolybdates, but not in rats exposed to molybdates in the absence of sulfide (Mills et al. 1981a). In rats, exposure to tetrathiomolybdates resulted in effects similar to those observed in ruminants including signs of copper deficiency, including loss of pigmentation in hair and a similar distribution of copper between the plasma proteins (Mills et al. 1981b). However, these interactions between tetrathiomolybdate and copper only occurred when both were present in the gastrointestinal tract (Mills et al. 1981b). It is not known if the interactions between copper and molybdenum only occur at higher molybdenum doses. As discussed by Brewer et al. (2000), tetrathiomolybdate can form a tripartite complex with copper and protein, which can prevent copper absorption through the gastrointestinal tract.

When tetrathiomolybdate is not administered with food, it can complex with copper and serum albumin, which prevents cellular uptake of copper. Due to these mechanisms, tetrathiomolybdate is used to treat individuals with Wilson's disease, which is a metabolic defect that limits the excretion of copper. Other molybdenum compounds may also interfere with copper balance in humans. Significant increases in serum and urine copper levels were observed in men exposed 0.022 mg molybdenum/kg/day (the source of molybdenum was high molybdenum sorghum supplemented with ammonium molybdate) for 10 days, as compared to exposure to 0.00771 mg molybdenum/kg/day for 10 days (Deosthale and Gopalan 1974). However, there was no difference in fecal excretion of copper, suggesting that copper absorption was not affected. In contrast, another study (Turnlund and Keys 2000) did not find any significant alterations in serum copper levels in humans exposed to molybdenum levels of 22–1,490 μg/day (0.0003–0.02 mg/kg/day) for 24 days (subjects were fed diets containing naturally high or low levels of molybdenum).

Other investigators have suggested that the molybdenum-induced effects are due to oxidative damage (Zhai et al. 2013; Zhang et al. 2013). Zhai et al. (2013) showed that the levels of two enzymatic antioxidants (superoxide dismutase and glutathione peroxidase) paralleled the molybdenum-induced sperm effects. Increases in antioxidant levels and improvements in sperm parameters were observed at lower molybdenum doses. However, at higher molybdenum doses, there were significant decreases in antioxidant levels and significant decreases in sperm motility and concentration and an increase in the rate of sperm abnormalities. Zhang et al. (2013) reported a similar finding for superoxide dismutase and glutathione peroxidase levels and the rate of MII oocyte abnormalities.

3.5.3 Animal-to-Human Extrapolations

There are limited data to evaluate potential differences in the toxicity of molybdenum between laboratory animals and humans. Most of the available oral exposure studies were conducted in rats, and human data are mostly limited to a small number of cross-sectional studies. Within laboratory animal species, some differences have been observed between rats and rabbits, with rabbits appearing to be more sensitive than rats. However, the studies are not directly comparable due to differences in the copper content and other dietary constituents. In the absence of data to the contrary, it is assumed that the toxicity of molybdenum will be similar across species (excluding ruminants, see Section 3.5.2).

3.6 HAZARD IDENTIFICATION AND MINIMAL RISK LEVELS

3.6.1 Hazard Identification

Systematic review of the available human and animal studies that assessed potential health effects associated with inhalation and oral exposure to molybdenum identified a number of potential targets of toxicity. Hazard identification conclusions for molybdenum, resulting from this systematic review, are presented in Appendix B and are summarized as follows:

- Molybdenum is presumed to cause respiratory effects following inhalation exposure, based on an inadequate level of evidence from human studies and a high level of evidence from animal studies.
- Molybdenum is suspected to cause hepatic effects, based on an inadequate level of evidence from human studies and a moderate level of evidence from animal studies.
- Molybdenum is presumed to cause renal effects, based on a high level of evidence from animal studies; human data are lacking.
- Molybdenum is suspected to cause reproductive effects, based on a low level of evidence from human studies and a moderate level of evidence from animal studies.
- The data are not classifiable as to determine whether molybdenum results in developmental toxicity because some human and animal studies have reported developmental effects and other studies have not found effects.
- The data are not classifiable as to determine whether molybdenum results in alterations in uric acid levels based on a high level of evidence of no effect in animal studies and an inadequate level of evidence from human studies.

3.6.2 Minimal Risk Levels (MRLs)

Estimates of exposure levels posing minimal risk to humans (MRLs) have been made for molybdenum. An MRL is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (noncarcinogenic) over a specified duration of exposure. MRLs are derived when reliable and sufficient data exist to identify the target organ(s) of effect or the most sensitive health effect(s) for a specific duration within a given route of exposure. MRLs are based on noncancerous health effects only and do not consider carcinogenic effects. MRLs can be derived for acute, intermediate, and chronic duration exposures for inhalation and oral routes. Appropriate methodology does not exist to develop MRLs for dermal exposure.

Although methods have been established to derive these levels (Barnes and Dourson 1988; EPA 1990), uncertainties are associated with these techniques. Furthermore, ATSDR acknowledges additional uncertainties inherent in the application of the procedures to derive less than lifetime MRLs. As an example, acute inhalation MRLs may not be protective for health effects that are delayed in development or are acquired following repeated acute insults, such as hypersensitivity reactions, asthma, or chronic bronchitis. As these kinds of health effects data become available and methods to assess levels of significant human exposure improve, these MRLs will be revised.

3.6.2.1 Inhalation MRLs

Acute-Duration. The database on the acute inhalation toxicity of molybdenum is limited to a study conducted by NTP (1997) that evaluated the effect of molybdenum trioxide on the nasal cavity and on body weight. No adverse effects were observed in the nasal cavity. However, weight loss was observed at the highest concentration tested (200 mg molybdenum/m^3); decreases in body weight gain were observed in male rats exposed to 67 mg molybdenum/m^3 and in female rats and mice exposed to 200 mg/m^3. Given the limited number of end points examined, the decrease in body weight gain was not considered a suitable basis for an acute-duration inhalation MRL because the database is inadequate for identifying the critical target of molybdenum toxicity following acute-duration inhalation exposure.

Intermediate-Duration. As with the acute-duration database, data on the intermediate-duration toxicity of molybdenum is limited to 90-day studies in rats and mice conducted by NTP (1997) that examined a wide range of potential targets, including reproductive end points. No toxicologically significant alterations were observed at concentrations of molybdenum trioxide as high as 67 mg/m^3. Consistent with ATSDR's practice of not using free-standing NOAELs as a point of departure (POD), an intermediate-duration inhalation MRL was not derived.

Chronic-Duration. There are limited data on the toxicity of inhaled molybdenum in humans. A study of workers at a molybdenite roasting facility exposed to molybdenum trioxide and other oxides found no alterations in lung function, but did find increases in serum uric acid levels (Walravens et al. 1979); the TWA molybdenum concentration was 9.46 mg molybdenum/m^3. Another study of workers exposed to ultrafine molybdenum trioxide dust reported respiratory symptoms (dyspnea and cough), radiographic abnormalities, and impaired lung function (Ott et al. 2004); the study did not provide monitoring data. Confidence in these cohort studies was considered very low (see Appendix B for additional information).

NTP (1997) conducted a 2-year study in rats and mice that examined a wide range of potential targets of toxicity. Adverse effects were limited to the respiratory tract, specifically the nasal respiratory and olfactory epithelium, epiglottis, and lungs. The specific types of lesions and the incidence data are presented in Table 3-6.

Benchmark dose (BMD) modeling was used to fit the data for effects with statistically significant increases in incidences at the lowest concentration (squamous metaplasia of the epiglottis in male and female rats and mice, hyaline degeneration of the nasal respiratory and olfactory epithelium in female rats, histiocyte infiltration in the lungs in male mice, and alveolar epithelial metaplasia in male and female mice); the results of the modeling are presented in Appendix A. Benchmark models provided adequate fit for most of the datasets, predicting benchmark concentrations (BMCs) ranging from 0.46 to 5.73 mg molybdenum/m^3 and 95% lower confidence limits on the BMC (BMCL) ranging from 0.19 to 4.26 mg molybdenum/m^3. Human equivalent concentrations (HECs) were calculated by adjusting the BMCLs for intermittent exposure (6 hours/day, 5 days/week) and multiplying by the regional deposited dose ratio (RDDR) for the appropriate region of the respiratory tract. The lowest HEC was 0.012 mg molybdenum/m^3 for squamous metaplasia of the epiglottis in female mice. This HEC was divided by an uncertainty factor of 30 (3 for extrapolation from animals to humans using dosimetric adjustments and 10 for human variability), resulting in an MRL of 0.0004 mg molybdenum/m^3.

3.6.2.2 Oral MRLs

Acute-Duration. A small number of studies have evaluated the acute toxicity of molybdenum. One human study (Deosthale and Gopalan 1974) that looked at a limited number of potential end points did not find alterations in urinary uric acid levels in subjects exposed to doses as high as 0.022 mg molybdenum/kg/day for 10 days. In rabbits, exposure to 1.2 mg molybdenum/kg/day as ammonium heptamolybdate in the diet for 14 days resulted in a 60% increase in serum triglyceride levels (Bersenyi et al. 2008); no histological alterations were observed in the liver or kidneys. The toxicological significance of this finding is not known and has not been reported in a study of male rabbits exposed to 0.58 mg molybdenum/kg/day as ammonium heptamolybdate (Bersenyi et al. 2008) or rats exposed to 60 mg molybdenum/kg/day as sodium molybdate for 90 days (Murray et al. 2013).

Reproductive effects have been observed in male and female mice and rabbits. In females, an increased rate of abnormal MII oocytes was observed at 11 mg molybdenum/kg/day in mice (Zhang et al. 2013); a second study did not find histological alterations in the ovaries of rabbits (Bersenyi et al. 2008). In males,

Table 3-6. Incidence of Non-Neoplastic Respiratory Tract Lesions in Rats and Mice Exposed to Molybdenum Trioxide for 2 Years

	Concentration (mg molybdenum/m^3)			
	0	6.7	20	67
Male rats				
Hyaline degeneration of nasal respiratory epithelium	2/50	7/49	48/49[a]	49/50[a]
Squamous metaplasia of epiglottis	0/49	11/48[a]	16/49[a]	39/49[a]
Chronic lung inflammation in alveolus	2/50	3/50	25/50[a]	47/50[a]
Female rats				
Hyaline degeneration of nasal respiratory epithelium	1/48	13/49[a]	50/50[a]	50/50[a]
Hyaline degeneration of nasal olfactory epithelium	39/48	47/49[b]	50/50[a]	50/50[a]
Squamous metaplasia of epiglottis	0/49	18/49[a]	29/49[a]	49/50[a]
Chronic lung inflammation	14/50	13/50	43/50[a]	49/50[a]
Male mice				
Nasal suppurative inflammation	2/50	6/50	10/49[b]	8/50[b]
Nasal olfactory epithelium atrophy	3/50	5/50	3/49	10/50[b]
Hyaline degeneration of nasal respiratory epithelium	11/50	13/50	11/49	41/50[a]
Squamous metaplasia of epiglottis	0/50	26/49[a]	37/48[a]	49/50[a]
Laryngeal hyperplasia	1/50	3/49	6/48	41/50
Histiocyte infiltration in the lungs	2/50	16/50[a]	9/49[b]	9/50[b]
Alveolar epithelial metaplasia	0/50	32/50[a]	36/49[a]	49/50[a]
Female mice				
Hyaline degeneration of nasal respiratory epithelium	26/49	23/50	28/49	48/49[a]
Hyaline degeneration of nasal olfactory epithelium	22/49	14/50	14/49	36/49[a]
Squamous metaplasia of epiglottis	1/49	36/50[a]	43/49[a]	49/50[a]
Laryngeal hyperplasia	1/49	1/50	7/49	35/50
Alveolar epithelial metaplasia	2/50	26/50[a]	39/49[a]	46/49[b]

[a]Significantly different from controls; p≤0.01.
[b]Significantly different from controls; p≤0.05.

Source: NTP 1997

a significant decrease in sperm concentration and motility and an increase in sperm abnormalities were observed at 25 mg molybdenum/kg/day in mice (Zhai et al. 2013); a rabbit study reported a reduction in mature spermatocytes in rabbits exposed to 0.58 mg molybdenum/kg/day, but did not report the incidence or statistical significance (Bersenyi et al. 2008). Although the Bersenyi et al. (2008) study in male rabbits identified the lowest LOAEL for reproductive effects, it was not selected as the basis of the acute MRL because the incidence of the reduction in mature spermatocytes was not reported. Rather, the Zhang et al. (2013) was selected as the key study for the acute-duration oral MRL.

The data were not considered suitable for BMD modeling (see Appendix A); thus, a NOAEL/LOAEL approach was used to identify the POD for the MRL. The MRL of 0.05 mg molybdenum/kg/day was calculated by dividing the NOAEL of 5.3 mg molybdenum/kg/day by an uncertainty factor of 100 (10 for extrapolation from animals to humans and 10 for human variability). It should be noted that the MRL is calculated based on the assumption of healthy dietary levels of molybdenum and copper and represents the level of exposure above and beyond the normal diet.

Intermediate-Duration. Studies in laboratory animals have evaluated the intermediate-duration toxicity of molybdenum. A number of adverse effects have been reported including kidney damage (Bompart et al. 1990; Murray et al. 2013), decreases in body weight gain (Bompart et al. 1990; Lyubimov et al. 2004; Mills et al. 1958; Murray et al. 2013; Van Reen and Williams 1956), hematological effects (Arrington and Davis 1953; Lyubimov et al. 2004), neurological effects (Arrington and Davis 1953), reproductive effects (Fungwe et al. 1990; Jeter and Davis 1954; Lyubimov et al. 2004; Murray et al. 2013; Pandey and Singh 2002), and developmental effects (Pandey and Singh 2002). The lowest LOAEL values identified are 1.5 mg molybdenum/kg/day for prolonged estrus phase without an effect on fertility in rats exposed to sodium molybdate in drinking water for 8 weeks (Fungwe et al. 1990) and 4.4 mg molybdenum/kg/day for anemia, decreases in body weight gain, and decreases in sperm motility and count in rats administered via gavage ammonium tetrathiomolybdate for 22–35 days (females) or 59–61 days (males) (Lyubimov et al. 2004). The observed renal effects included slight diffuse hyperplasia in rats exposed to 60 mg molybdenum/kg/day as sodium molybdate in the diet (Murray et al. 2013) and increases in diuresis and creatinuria and decreases in creatinine clearance in rats administered 80 mg molybdenum/kg/day as ammonium heptamolybdate (Bompart et al. 1990); the NOAELs identified in these studies are 17 and 40 mg molybdenum/kg/day, respectively. Two studies have reported hematological effects—decreases in erythrocyte count, hemoglobin concentrations, and hematocrit levels in rats exposed to 4.4 mg molybdenum/kg/day as ammonium tetrathiomolybdate (Lyubimov et al. 2004) and in rabbits exposed to 54 mg molybdenum/kg/day as sodium molybdate (Arrington and Davis 1953);

however, other studies have not found hematological effects in rats exposed to 60 or 70 mg molybdenum/kg/day as sodium molybdate (Gray and Daniel 1954; Murray et al. 2013). Neurological effects consisting of weakness of the front legs progressing to an "inability to maintain weight and legs spread outward" was observed in young rabbits exposed to 54 mg molybdenum/kg/day as sodium molybdate (Arrington and Davis 1953); no neurological effects were observed at 25 mg molybdenum/kg/day or in mature rabbits exposed to doses as high as 120 mg molybdenum/kg/day (Arrington and Davis 1953). Although several studies have reported reproductive effects, particularly alterations in sperm parameters, there is considerable overlap between the identified NOAELs and LOAELs that are summarized in Table 3-2. Some of the overlap may be explained by the copper content of the diet. In the Jeter and Davis (1954) and Murray et al. (2013) studies, the copper content of the diet exceeded the recommended intake for rats (5 ppm) (NAS 1995) by a factor of 4 or 2.8, respectively. Four studies examined the developmental toxicity of molybdenum following intermediate-duration exposure. No alterations in resorptions, post-implantation losses, or fetal body weights were observed in three studies with doses as high as 37.5 mg molybdenum/kg/day (Jeter and Davis 1954; Lyubimov et al. 2004; Murray et al. 2014). A fourth study reported increases in post-implantation losses, increased resorption, and decreases in fetal growth in a study in which males only were administered 14 mg molybdenum/kg (5 days/week) for 60 days (Pandey and Singh 2002).

Reproductive toxicity in males and females consistently has the lowest LOAEL values. Reproductive effects have also been observed following acute-duration exposure, and the systematic review of the available human and animal data (Appendix B) showed that reproductive toxicity is "suspected to be a health effect following oral exposure." The Fungwe et al. (1990) study identified the lowest LOAEL of 1.5 mg molybdenum/kg/day; the NOAEL was 0.76 mg molybdenum/kg/day.

BMD modeling of the estrous cycle length data from the Fungwe et al. (1990) study was conducted to identify the POD for the MRL using a benchmark response (BMR) of 1 SD change from the control. The continuous variable models did not adequately fit the data and a NOAEL/LOAEL approach was used to identify the POD for the MRL. An MRL of 0.008 mg/kg/day was derived by dividing the NOAEL of 0.76 mg molybdenum/kg/day by an uncertainty factor of 100 (10 for extrapolation from animals to humans and 10 for human variability). The MRL is calculated based on the assumption of healthy dietary levels of molybdenum and copper and represents the level of exposure above and beyond the normal diet. The MRL is approximately 10-fold higher than the recommended dietary allowance of 0.0006 mg/kg/day (estimated using a reference body weight of 70 kg) (NAS 2001).

Chronic-Duration. Data on the chronic toxicity of molybdenum come from several population-based studies; most of these studies looked for associations between background exposure to molybdenum and adverse health outcomes. No laboratory animal studies were identified. Koval'skiy et al. (1961) found increases in blood uric acid and symptoms of gout in residents living in Armenia with high levels of molybdenum in the soil and food; the investigators estimated that the residents were exposed to 10–15 mg/day (0.14–0.21 mg/kg/day). A series of small studies of residents living in areas of Colorado with high levels of molybdenum in the drinking water did not find significant increases in uric acid levels; one study estimated that molybdenum intake was 500 μg/day (0.007 mg/kg/day) (EPA 1979). Other studies have found significant associations between serum or urinary molybdenum levels and the severity of complications from diabetes (Rodriguez Flores et al. 2011), high blood pressure (Yorita Christensen 2013), semen quality (Meeker et al. 2008), testosterone levels (Meeker et al. 2010), and psychomotor index in infants (molybdenum levels were measured in the mothers) (Vazques-Salas et al. 2014). However, none of these studies established causality, and the molybdenum levels accounted for only a small percentage of the variance. No chronic-duration animal toxicity studies were identified.

Although the Koval'sky et al. (1961) study provided an estimated dose, the study was not considered suitable for derivation of a chronic-duration oral MRL for molybdenum. The study has a number of deficiencies that limit the interpretation of the results: (1) the control group consisted of 5 individuals compared to 52 subjects in the exposed group; (2) no information was provided on the controls to assess whether they were matched to the exposed group; (3) it does not appear that the study controlled for potential confounders, such as diet and alcohol, which can increase uric acid levels; and (4) NAS (2001) noted that there were potential analytical problems with the measurement of serum and urine copper levels.

3.7 TOXICITIES MEDIATED THROUGH THE NEUROENDOCRINE AXIS

Recently, attention has focused on the potential hazardous effects of certain chemicals on the endocrine system because of the ability of these chemicals to mimic or block endogenous hormones. Chemicals with this type of activity are most commonly referred to as *endocrine disruptors*. However, appropriate terminology to describe such effects remains controversial. The terminology *endocrine disruptors*, initially used by Thomas and Colborn (1992), was also used in 1996 when Congress mandated the EPA to develop a screening program for "...certain substances [which] may have an effect produced by a naturally occurring estrogen, or other such endocrine effect[s]...". To meet this mandate, EPA convened a panel called the Endocrine Disruptors Screening and Testing Advisory Committee (EDSTAC), and in

1998, the EDSTAC completed its deliberations and made recommendations to EPA concerning *endocrine disruptors*. In 1999, the National Academy of Sciences released a report that referred to these same types of chemicals as *hormonally active agents*. The terminology *endocrine modulators* has also been used to convey the fact that effects caused by such chemicals may not necessarily be adverse. Many scientists agree that chemicals with the ability to disrupt or modulate the endocrine system are a potential threat to the health of humans, aquatic animals, and wildlife. However, others think that endocrine-active chemicals do not pose a significant health risk, particularly in view of the fact that hormone mimics exist in the natural environment. Examples of natural hormone mimics are the isoflavinoid phytoestrogens (Adlercreutz 1995; Livingston 1978; Mayr et al. 1992). These chemicals are derived from plants and are similar in structure and action to endogenous estrogen. Although the public health significance and descriptive terminology of substances capable of affecting the endocrine system remains controversial, scientists agree that these chemicals may affect the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body responsible for maintaining homeostasis, reproduction, development, and/or behavior (EPA 1997). Stated differently, such compounds may cause toxicities that are mediated through the neuroendocrine axis. As a result, these chemicals may play a role in altering, for example, metabolic, sexual, immune, and neurobehavioral function. Such chemicals are also thought to be involved in inducing breast, testicular, and prostate cancers, as well as endometriosis (Berger 1994; Giwercman et al. 1993; Hoel et al. 1992).

No studies were located regarding endocrine disruption in humans and/or animals after exposure to molybdenum. No *in vitro* studies were located regarding endocrine disruption of molybdenum.

3.8 CHILDREN'S SUSCEPTIBILITY

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans, when most biological systems will have fully developed. Potential effects on offspring resulting from exposures of parental germ cells are considered, as well as any indirect effects on the fetus and neonate resulting from maternal exposure during gestation and lactation. Relevant animal and *in vitro* models are also discussed.

Children are not small adults. They differ from adults in their exposures and may differ in their susceptibility to hazardous chemicals. Children's unique physiology and behavior can influence the extent of their exposure. Exposures of children are discussed in Section 6.6, Exposures of Children.

Children sometimes differ from adults in their susceptibility to adverse health effects from exposure to hazardous chemicals, but whether there is a difference depends on the chemical(s) (Guzelian et al. 1992; NRC 1993). Children may be more or less susceptible than adults to exposure-related health effects, and the relationship may change with developmental age (Guzelian et al. 1992; NRC 1993). Vulnerability often depends on developmental stage. There are critical periods of structural and functional development during both prenatal and postnatal life that are most sensitive to disruption from exposure to hazardous substances. Damage from exposure in one stage may not be evident until a later stage of development. There are often differences in pharmacokinetics and metabolism between children and adults. For example, absorption may be different in neonates because of the immaturity of their gastrointestinal tract and their larger skin surface area in proportion to body weight (Morselli et al. 1980; NRC 1993); the gastrointestinal absorption of lead is greatest in infants and young children (Ziegler et al. 1978). Distribution of xenobiotics may be different; for example, infants have a larger proportion of their bodies as extracellular water, and their brains and livers are proportionately larger (Altman and Dittmer 1974; Fomon 1966; Fomon et al. 1982; Owen and Brozek 1966; Widdowson and Dickerson 1964). Past literature has often described the fetus/infant as having an immature (developing) blood-brain barrier that is leaky and poorly intact (Costa et al. 2004). However, current evidence suggests that the blood-brain barrier is anatomically and physically intact at this stage of development, and the restrictive intracellular junctions that exist at the blood-CNS interface are fully formed, intact, and functionally effective (Saunders et al. 2008, 2012).

However, during development of the brain, there are differences between fetuses/infants and adults that are toxicologically important. These differences mainly involve variations in physiological transport systems that form during development (Ek et al. 2012). These transport mechanisms (influx and efflux) play an important role in the movement of amino acids and other vital substances across the blood-brain barrier in the developing brain; these transport mechanisms are far more active in the developing brain than in the adult. Because many drugs or potential toxins may be transported into the brain using these same transport mechanisms—the developing brain may be rendered more vulnerable than the adult. Thus, concern regarding possible involvement of the blood-brain barrier with enhanced susceptibility of the developing brain to toxins is valid. It is important to note however, that this potential selective vulnerability of the developing brain is associated with essential normal physiological mechanisms; and not because of an absence or deficiency of anatomical/physical barrier mechanisms.

The presence of these unique transport systems in the developing brain of the fetus/infant is intriguing; whether these mechanisms provide protection for the developing brain or render it more vulnerable to toxic injury is an important toxicological question. Chemical exposure should be assessed on a case-by-case basis. Research continues into the function and structure of the blood-brain barrier in early life (Kearns et al. 2003; Saunders et al. 2012; Scheuplein et al. 2002).

Many xenobiotic metabolizing enzymes have distinctive developmental patterns. At various stages of growth and development, levels of particular enzymes may be higher or lower than those of adults, and sometimes unique enzymes may exist at particular developmental stages (Komori et al. 1990; Leeder and Kearns 1997; NRC 1993; Vieira et al. 1996). Whether differences in xenobiotic metabolism make the child more or less susceptible also depends on whether the relevant enzymes are involved in activation of the parent compound to its toxic form or in detoxification. There may also be differences in excretion, particularly in newborns given their low glomerular filtration rate and not having developed efficient tubular secretion and resorption capacities (Altman and Dittmer 1974; NRC 1993; West et al. 1948). Children and adults may differ in their capacity to repair damage from chemical insults. Children also have a longer remaining lifetime in which to express damage from chemicals; this potential is particularly relevant to cancer.

Certain characteristics of the developing human may increase exposure or susceptibility, whereas others may decrease susceptibility to the same chemical. For example, although infants breathe more air per kilogram of body weight than adults breathe, this difference might be somewhat counterbalanced by their alveoli being less developed, which results in a disproportionately smaller surface area for alveolar absorption (NRC 1993).

There are limited data on the toxicity of molybdenum in children. In studies in rat pups maintained on a caries-promoting diet, administration of 50 mg molybdenum/kg/day as sodium molybdate resulted in an increase in buccal enamel lesions (Hunt and Navia 1975), but exposure to 8 mg molybdenum/kg/day did not result in increases in dental caries (Van Reen et al. 1962). Arrington and Davis (1953) exposed young (6 weeks of age at the start of the study) and mature rabbits to sodium molybdate in the diet for 30–84 days. Marked muscular/skeletal effects were observed in the young rabbits, but were not observed in the mature rabbits. Since the investigators did not provide information on dietary intake, it is difficult to make direct comparisons across the studies.

An observational study did not find an association between maternal urinary molybdenum levels and newborn body weight or infant mental development (Shirai et al. 2010). But another study did find an association between third-trimester maternal urinary molybdenum levels and infant psychomotor development indices (Vazquez-Salas et al. 2014). Two rat studies in which the copper content of the diet was adequate did not find significant alterations in fetal growth, survival, or malformations at maternal doses of 4.4 or 38 mg molybdenum/kg/day (Lyubimov et al. 2004; Murray et al. 2014). However, a third study reported decreases in growth and number of live fetuses in the offspring of male rats administered 14 mg molybdenum/kg as sodium molybdate 5 days/week for 60 days prior to mating with unexposed females (Pandey and Singh 2002).

3.9 BIOMARKERS OF EXPOSURE AND EFFECT

Biomarkers are broadly defined as indicators signaling events in biologic systems or samples. They have been classified as markers of exposure, markers of effect, and markers of susceptibility (NAS/NRC 1989).

The National Report on Human Exposure to Environmental Chemicals provides an ongoing assessment of a generalizable sample of the exposure of the U.S. population to environmental chemicals using biomonitoring. This report is available at http://www.cdc.gov/exposurereport/. The biomonitoring data for molybdenum from this report is discussed in Section 6.5. A biomarker of exposure is a xenobiotic substance or its metabolite(s) or the product of an interaction between a xenobiotic agent and some target molecule(s) or cell(s) that is measured within a compartment of an organism (NAS/NRC 1989). The preferred biomarkers of exposure are generally the substance itself, substance-specific metabolites in readily obtainable body fluid(s), or excreta. However, several factors can confound the use and interpretation of biomarkers of exposure. The body burden of a substance may be the result of exposures from more than one source. The substance being measured may be a metabolite of another xenobiotic substance (e.g., high urinary levels of phenol can result from exposure to several different aromatic compounds). Depending on the properties of the substance (e.g., biologic half-life) and environmental conditions (e.g., duration and route of exposure), the substance and all of its metabolites may have left the body by the time samples can be taken. It may be difficult to identify individuals exposed to hazardous substances that are commonly found in body tissues and fluids (e.g., essential mineral nutrients such as copper, zinc, and selenium). Biomarkers of exposure to molybdenum are discussed in Section 3.9.1.

Biomarkers of effect are defined as any measurable biochemical, physiologic, or other alteration within an organism that, depending on magnitude, can be recognized as an established or potential health impairment or disease (NAS/NRC 1989). This definition encompasses biochemical or cellular signals of tissue dysfunction (e.g., increased liver enzyme activity or pathologic changes in female genital epithelial cells), as well as physiologic signs of dysfunction such as increased blood pressure or decreased lung capacity. Note that these markers are not often substance specific. They also may not be directly adverse, but can indicate potential health impairment (e.g., DNA adducts). Biomarkers of effects caused by molybdenum are discussed in Section 3.9.2.

A biomarker of susceptibility is an indicator of an inherent or acquired limitation of an organism's ability to respond to the challenge of exposure to a specific xenobiotic substance. It can be an intrinsic genetic or other characteristic or a preexisting disease that results in an increase in absorbed dose, a decrease in the biologically effective dose, or a target tissue response. If biomarkers of susceptibility exist, they are discussed in Section 3.11, Populations That Are Unusually Susceptible.

3.9.1 Biomarkers Used to Identify or Quantify Exposure to Molybdenum

Molybdenum levels can readily be measured in tissues, body fluids, and excreta. Dose-related increases in serum molybdenum levels were observed in rats and mice exposed via inhalation to molybdenum trioxide for 2 years (NTP 1997). In a study examining the relationship between plasma molybdenum levels and dietary intake, Turnland and Keyes (2004) reported a baseline plasma molybdenum level of 8.2±.5 nmol/L; 25 days after the subjects were maintained on a low molybdenum diet (22 μg/day), the plasma molybdenum level was 5.1±0.5 nmol/L. Although a significant correlation between plasma molybdenum and dietary molybdenum was observed, comparison between plasma molybdenum levels at different dietary intakes showed that a significant increase in plasma molybdenum was not observed until the dietary intake exceeded 460 μg/day (6.6 mg/kg/day) and that tripling the intake resulted in a doubling of the plasma molybdenum levels. Urinary molybdenum levels were also significantly correlated to dietary intakes (Turnland and Keyes 2004) and appeared to be more responsive to changes in dietary intake. At all dietary concentrations, the urinary molybdenum levels were slightly lower than the dietary intakes (Turnland and Keyes 2004). The investigators concluded that plasma molybdenum levels were an indicator of dietary intake, but urinary levels were more directly related to molybdenum intake.

Molybdenum levels were measured in urine samples collected during National Health and Nutrition Surveys. The geometric mean urinary molybdenum levels in the United States in 2011–2012 was 37.1 μg/L and the creatinine-corrected value was 42.0 μg/g creatinine (CDC 2015); see Section 6.5 for additional information.

Although several studies have reported molybdenum levels in hair samples (DiPietro et al. 1989; Nagra et al. 1992; Paschal et al. 1989), no relationship between molybdenum exposure and hair levels has been established. Furthermore, Miekeley et al. (1998) demonstrated large interlaboratory differences in the molybdenum levels measured in hair.

3.9.2 Biomarkers Used to Characterize Effects Caused by Molybdenum

No biomarkers to characterize effects caused by molybdenum have been identified.

3.10 INTERACTIONS WITH OTHER CHEMICALS

The interaction between copper and molybdenum has been well-established in animals. The levels of copper in the diet have been shown to influence the toxicity of molybdenum. Marked toxicity has been reported in studies in which the copper content of the diet was inadequate. Observed effects included mortality (Valli et al. 1969; Widjajakuma et al. 1973), marked decreases in body weight gain and weight loss (Brinkman and Miller 1961; Johnson and Miller 1961; Sasmal et al. 1968; Valli et al. 1969; Van Reen 1959), and anemia (Brinkman and Miller 1961; Franke and Moxon 1937; Gray and Daniel 1954; Johnson et al. 1969; Valli et al. 1969). In general, these effects (or the severity of the effects) have not been observed when the diet contains an adequate level of copper (Mills et al. 1958; Murray et al. 2013; Pandey and Singh 2002; Peredo et al. 2013). Exposure to high levels of copper has been shown to reduce the toxicity of molybdenum. Administration of high doses of copper to moribund rabbits resulted in a return to normal body weight gain and increases in hemoglobin levels within 2–3 weeks (Arrington and Davis 1953). Lyubimov et al. (2004) showed that administration of a high dose of copper prevented the molybdenum-induced testicular toxicity observed in rats fed a copper-adequate diet. Similarly, in an environmental exposure study, Meeker et al. (2008) found a greater decline in sperm concentration in men with high molybdenum blood levels and copper blood levels below the median, as compared to when the men were not stratified by blood copper levels.

Kinetic studies have demonstrated differences in plasma, liver, and kidney copper and molybdenum concentrations in rats fed copper-deficient, copper-adequate, and copper-excessive diets (Nederbragt 1980). Excess copper in the diet resulted in a smaller increase in copper concentrations in plasma, liver, and kidneys and molybdenum concentrations in the liver and kidney, as compared to levels in rats fed a copper-adequate diet. Similarly, lower rises in liver copper and molybdenum and kidney molybdenum levels were observed in rats fed a copper-deficient and high-molybdenum diet, as compared to the copper-adequate diet. At the lowest molybdenum dose, kidney molybdenum levels were higher in the copper-deficient groups. In another study (Nederbragt 1982), kidney levels of copper and molybdenum were 5 and 3 times higher, respectively, in the copper-adequate groups as compared to the copper-deficient group. Two human studies have also evaluated the effect of molybdenum on copper levels. In one study, increases in serum and urine copper levels were found following a 10-day exposure to 0.022 mg molybdenum/kg/day (Deosthale and Gopalan 1974). Another study found no significant alterations in serum copper levels in humans exposed to 0.0003–0.02 mg molybdenum/kg/day for 24 days (Turnlund and Keys 2000).

3.11 POPULATIONS THAT ARE UNUSUALLY SUSCEPTIBLE

A susceptible population will exhibit a different or enhanced response to molybdenum than will most persons exposed to the same level of molybdenum in the environment. Factors involved with increased susceptibility may include genetic makeup, age, health and nutritional status, and exposure to other toxic substances (e.g., cigarette smoke). These parameters result in reduced detoxification or excretion of molybdenum, or compromised function of organs affected by molybdenum. Populations who are at greater risk due to their unusually high exposure to molybdenum are discussed in Section 6.7, Populations with Potentially High Exposures.

The available data demonstrate the interaction between copper and molybdenum; more severe effects are observed in animals maintained on a copper-deficient diet (Brinkman and Miller 1961; Franke and Moxon 1961; Johnson and Miller 1961; Sasmal et al. 1968; Valli et al. 1969; Van Reen 1959; Widjajakuma et al. 1973). Administration of additional copper results in a reversal of the adverse effect (Arrington and Davis 1953). The findings in the animal studies are supported by a report by Koval'skiy et al. (1961) that gout-like symptoms and increased uric acid levels were observed in a population with high molybdenum levels in the soil and low copper intakes, but were not observed in an area with high molybdenum levels and adequate copper intakes. Thus, individuals with low copper intakes may be unusually susceptible to the toxicity of molybdenum.

Studies in rats suggest that the toxicity of molybdenum may be increased in animals maintained on a low protein diet. The magnitudes of the decrease in body weight gain (Bandyopadhyay et al. 1981; Cox et al. 1960) and decreases in femur breaking strength (Fejery et al. 1983) were greater in rats exposed to a low protein diet, as compared to those maintained on a diet with sufficient protein.

Since molybdenum is primarily excreted in the urine, individuals with kidney disease may also be more susceptible to molybdenum toxicity; however, this has not been investigated in humans or animals.

3.12 METHODS FOR REDUCING TOXIC EFFECTS

This section will describe clinical practice and research concerning methods for reducing toxic effects of exposure to molybdenum. Because some of the treatments discussed may be experimental and unproven, this section should not be used as a guide for treatment of exposures to molybdenum. When specific exposures have occurred, poison control centers, board certified medical toxicologists, board-certified occupational medicine physicians and/or other medical specialists with expertise and experience treating patients overexposed to molybdenum can be consulted for medical advice.

No texts were located that provided specific information about treatment following exposures to molybdenum.

Additional relevant information can be found in the front section of this profile under QUICK REFERENCE FOR HEALTH CARE PROVIDERS.

3.12.1 Reducing Peak Absorption Following Exposure

There are no established methods for managing initial exposure to molybdenum or for reducing peak absorption.

3.12.2 Reducing Body Burden

Molybdenum is readily eliminated from the body, and there is evidence that ingestion of high molybdenum doses results in physiological adaptations that increase urinary excretion (Novotny and Turnlund 2007).

3.12.3 Interfering with the Mechanism of Action for Toxic Effects

The mechanism of molybdenum toxicity has not been well established. Studies in laboratory animals suggest that co-administration of a high copper diet can reduce the toxicity of molybdenum, but this has not been tested in humans, and exposure to high levels of copper may be toxic.

3.13 ADEQUACY OF THE DATABASE

Section 104(I)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of molybdenum is available. Where adequate information is not available, ATSDR, in conjunction with the National Toxicology Program (NTP), is required to assure the initiation of a program of research designed to determine the adverse health effects (and techniques for developing methods to determine such health effects) of molybdenum.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that if met would reduce the uncertainties of human health risk assessment. This definition should not be interpreted to mean that all data needs discussed in this section must be filled. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

3.13.1 Existing Information on Health Effects of Molybdenum

The existing data on health effects of inhalation, oral, and dermal exposure of humans and animals to molybdenum are summarized in Figure 3-5. The purpose of this figure is to illustrate the existing information concerning the health effects of molybdenum. Each dot in the figure indicates that one or more studies provide information associated with that particular effect. The dot does not necessarily imply anything about the quality of the study or studies, nor should missing information in this figure be interpreted as a “data need”. A data need, as defined in ATSDR’s *Decision Guide for Identifying Substance-Specific Data Needs Related to Toxicological Profiles* (Agency for Toxic Substances and Disease Registry 1989), is substance-specific information necessary to conduct comprehensive public health assessments. Generally, ATSDR defines a data gap more broadly as any substance-specific information missing from the scientific literature. A more detailed summary of the number of studies examining specific end points is presented in Tables B-3 and B-4 in Appendix B.

Data on the toxicity of inhaled molybdenum are limited to two occupational exposure studies in which the exposure is poorly characterized. A number of cross-sectional studies have examined the associations between a biomarker of molybdenum exposure (blood or urine levels) and a specific health effect. These studies are not sufficient to establish causality. Additionally, one study examined a community living in an area with high levels of molybdenum in the soil and locally grown foodstuffs. Human data on the

Figure 3-5. Existing Information on Health Effects of Molybdenum

Human

	Death	Systemic: Acute	Systemic: Intermediate	Systemic: Chronic	Immunologic/Lymphoretic	Neurologic	Reproductive	Developmental	Genotoxic	Cancer
Inhalation				●						●
Oral				●			●	●		
Dermal										

Animal

	Death	Systemic: Acute	Systemic: Intermediate	Systemic: Chronic	Immunologic/Lymphoretic	Neurologic	Reproductive	Developmental	Genotoxic	Cancer
Inhalation	●	●	●	●	●	●	●			●
Oral	●	●	●			●	●	●	●	
Dermal					●					

● Existing Studies

dermal toxicity of molybdenum are limited to two patch testing studies of individuals undergoing knee or hip replacement.

Acute-duration studies examining a limited number of end points and comprehensive intermediate- and chronic-duration studies in rats and mice have investigated the inhalation toxicity of molybdenum. The chronic studies provided evidence that the respiratory tract is a primary target of toxicity and suggestive evidence of carcinogenicity; the intermediate-duration study did not identify adverse health effects. A number of studies in laboratory animals have examined the oral toxicity of molybdenum following acute- or intermediate-duration exposures. Studies in which the basal diet contained adequate levels of copper identified several targets of toxicity including the kidney, liver, and reproductive system; there was some indication that molybdenum exposure may also result in alterations in uric acid levels and developmental toxicity, but the data were not considered adequate for conclusive hazard identification. Data on the dermal toxicity of molybdenum are limited to a guinea pig sensitization assay.

3.13.2 Identification of Data Needs

Acute-Duration Exposure. No data were located regarding health effects after acute inhalation exposure to molybdenum in humans. In laboratory animals, the inhalation exposure data are limited to studies conducted in rats and mice (NTP 1997); however, the studies only examined the nasal cavity and body weight. Although increased mortality and decreases in body weight gain were observed, the studies are not adequate for identifying the primary target of toxicity. Thus, they were not considered adequate for derivation of an acute-duration inhalation MRL. Additional studies examining a wide-range of end points would be useful for characterizing the hazard of molybdenum following acute inhalation exposure.

In an acute experiment, no alterations in uric acid levels were observed in volunteers (Deosthale and Gopalan 1974); the study did not examine other potential end points. A small number of studies have examined the acute oral toxicity in laboratory animals, and none of them examined a wide-range of end points. One study found an increase in serum triglyceride levels in rabbits, but did not find any histological alterations in the liver or kidneys (Bersenyi et al. 2008). Three studies examining reproductive end points suggest that this is a sensitive target of acute molybdenum toxicity (Bersenyi et al. 2008; Zhai et al. 2013; Zhang et al. 2013). These studies identified LOAELs for effects on oocytes and sperm and were used to derive an acute-duration oral MRL for molybdenum.

Data on the dermal toxicity of molybdenum are limited to a contact sensitization study in guinea pigs, which found positive effects (Boman et al. 1979). The acute dermal toxicity database is considered inadequate for identifying sensitive targets of toxicity; additional studies examining a wide range of potential end points are needed.

Intermediate-Duration Exposure. The available data on the toxicity of molybdenum following intermediate-duration inhalation exposure are limited to 90-day studies examining a wide range of potential targets of toxicity in rats and mice (NTP 1997). No adverse effects were observed in these studies, and the studies were not considered suitable for derivation of an intermediate-duration inhalation MRL for molybdenum. Additional studies testing higher concentrations may identify sensitive targets.

A number of studies have examined the intermediate-duration toxicity of ingested molybdenum. Among studies in which the laboratory animals were provided a diet with adequate levels of copper, a number of targets of toxicity were identified including the liver, kidney, reproductive system, and possibly the developing organism (Bompart et al. 1990; Fungwe et al. 1990; Jeter and Davis 1954; Lyubimov et al. 2004; Murray et al. 2013; Pandey and Singh 2002). Based on a comparison of LOAEL values, the reproductive system appeared to be the most sensitive target of toxicity. An intermediate-duration oral MRL was derived based on alterations in oocyte morphology (Fungwe et al. 1990).

No studies have examined the dermal toxicity of molybdenum following intermediate-duration exposure; studies are needed to identify potential targets of toxicity for humans.

Chronic-Duration Exposure and Cancer. Two occupational exposure studies have reported mixed results on the effect of molybdenum on the respiratory tract (Ott et al. 2004; Walravens et al. 1979). There is insufficient information on the specific molybdenum compounds involved and limited data on exposure levels. Chronic exposure studies in rats and mice have identified the respiratory tract as a sensitive target of molybdenum toxicity (NTP 1997), and an inhalation MRL was derived based on the findings in the animal studies.

A number of studies have evaluated the chronic toxicity of ingested molybdenum in humans. A study of residents living in an area of Armenia with high molybdenum and low copper levels in the soil found increases in uric acid levels and gout-like symptoms (Koval'skiy et al. 1961); other studies in which residents were exposed to high levels of molybdenum in the water did not find alterations in uric acid (EPA 1979). Other studies that examined the potential of molybdenum to induce adverse health effects presumably involved background environmental exposure (Meeker et al. 2008, 2010; Mendy et al. 2012; Schroeder and Kraemer 1974; Shiue and Hristova 2014; Vazquez-Salas et al. 2014; Yorita Christensen 2013). Although some of these studies reported statistically significant associations between biomarkers of molybdenum exposure (plasma or urine levels) and adverse effects, the studies do not establish causality and there may have been factors other than molybdenum exposure. No laboratory animal studies evaluated the chronic oral toxicity of molybdenum. Additional studies examining a wide range of potential end points are needed to identify the hazards associated with chronic ingestion of high levels of molybdenum and establish dose-response relationships.

One study evaluated the carcinogenicity of molybdenum in humans (Droste et al. 1999) and found a higher risk of lung cancer among workers in jobs related to molybdenum exposure; however, there was potential exposure to a number of other carcinogens. In the NTP (1997) rat and mouse studies, equivocal evidence for lung cancer was observed in male rats and some evidence of carcinogenicity was observed in male and female mice. No studies have examined the carcinogenicity of molybdenum following oral or dermal exposure. Chronic studies by these routes of exposure are needed to evaluate carcinogenicity.

Genotoxicity. There are limited data on the *in vivo* genotoxicity of molybdenum; a mouse study found weakly positive effects for micronuclei formation and dominant lethality (Titenko-Holland et al. 1998). Additional *in vivo* studies, as well as monitoring workers for genotoxicity, would be useful for assessing the genotoxic potential in humans. *In vitro* studies were negative for micronuclei formation (Gibson et al. 1997; Titenko-Holland et al. 1998) and positive for chromosomal aberrations and sister chromatid exchange (NTP 1997), but both were only tested in one study. Mixed results were found in tests of DNA repair, which may be reflective of the molybdenum compound tested (Kanematsu et al. 1980; Nishioka 1975); additional studies are needed to clarify these conflicting results.

Reproductive Toxicity. A study of men at an infertility clinic found associations between blood molybdenum levels and altered sperm parameters and reproductive hormone levels (Meeker et al. 2008, 2010). These studies do not establish causality; however, oral exposure studies in laboratory animals support the reproductive system as a target of molybdenum toxicity (Bersenyi et al. 2008; Fungwe et al. 1990; Lyubimov et al. 2004; Pandey and Singh 2002; Zhai et al. 2013; Zhang et al. 2013). Although reproductive effects are the basis of the acute- and intermediate-duration oral MRLs for molybdenum, there is considerable inconsistency across studies, and some studies testing higher doses have not found effects (Jeter and Davis 1954; Murray et al. 2013). Additional studies designed to assess potential differences in routes of oral exposure and with different molybdenum compounds could help explain the conflicting results.

Developmental Toxicity. Two studies examined whether there was a relationship between molybdenum exposure and developmental effects in humans (Shirai et al. 2010; Vazquez-Salas et al. 2014) and found mixed results. Two studies in rats failed to find a relationship between oral exposure to molybdenum and birth outcomes (Lyubimov et al. 2004; Murray et al. 2014). A third study found decreases in fetal growth in a male-only exposure study (Pandey and Singh 2002).

Immunotoxicity. The immunotoxicity of molybdenum has not been adequately addressed. No inhalation or oral exposure studies addressed immune function; intermediate- and chronic-duration inhalation studies did not find histological alterations in the thymus or spleen (NTP 1997). Very low levels of positive results of patch tests were observed in patients undergoing hip or knee replacements (Koster et al. 2000; Menezes et al. 2004; Zeng et al. 2014). In animals, contact sensitization was observed in guinea pigs in a sensitization assay with molybdenum pentachloride (Boman et al. 1979). Studies examining immune function would be useful in evaluating whether this is a target of molybdenum toxicity.

Neurotoxicity. There are limited data on the neurotoxicity of molybdenum. No histological alterations in the brain or overt signs of toxicity were observed in laboratory animals after intermediate-duration inhalation (NTP 1997) or oral (Murray et al. 2013) exposure or chronic-duration inhalation exposure (NTP 1997). Additional studies, particularly in young animals, should be conducted to assess whether molybdenum affects the neuromuscular system, in the absence of copper deficiency.

Epidemiological and Human Dosimetry Studies. A small number of epidemiology studies were identified for molybdenum; however, most of these studies presumably involve background environmental exposure to molybdenum. Two occupational exposure studies found conflicting results regarding the respiratory toxicity of molybdenum (Walravens et al. 197; Ott et al. 2004). Additional studies of worker populations examining a wide range of potential end points, including the respiratory tract, would provide valuable information on the toxicity of inhaled molybdenum. General population studies have identified a number of potential targets of toxicity of ingested molybdenum including blood pressure (Shiue and Hrisova 2014), liver (Mendy et al. 2012), the reproductive system (Meeker et al. 2008, 2010), and the developing organism (Shirai et al. 2010); however, none of the studies established causality. Studies of populations exposed to high levels of molybdenum in drinking water or from foods grown in molybdenum-rich soil would provide support for establishing sensitive targets of molybdenum toxicity. One study of a community living in an area with high molybdenum in the soil reported gout-like symptoms and increased uric acid levels (Koval'skiy et al. 1961); however, low intakes of copper may have contributed to these effects. Additional studies to confirm the results of this study would be valuable.

Biomarkers of Exposure and Effect.

Exposure. Molybdenum levels can be measured in blood, tissues, and excreta, and background urinary levels of molybdenum have been established in healthy individuals (CDC 2015). Blood and urinary levels have been shown to increase in response to increased molybdenum ingestion (Turnland and Keyes 2004), although plasma molybdenum levels are likely to be reflective of recent dietary intake. Studies that quantified the relationship between blood and/or urinary levels and intake would provide valuable information on screening and comparison with adverse effect levels.

Effect. No biomarkers of effect were identified. The available data have identified the following sensitive targets: respiratory tract (inhalation only), kidney, and reproductive system. Studies examining the possible relationship between blood or urinary levels of molybdenum with these adverse health effects could facilitate medical surveillance leading to early detection and possible treatment.

Absorption, Distribution, Metabolism, and Excretion. For humans, detailed quantitative information is available regarding the absorption, distribution, and excretion of ingested molybdate ($Mo^{[VI]}O_4^{2-}$) and molybdenum incorporated into food. Although molybdate is most likely the dominant chemical species of molybdenum in the body, there are no data for humans on toxicokinetics following exposures to other forms of molybdenum that could occur in the environment, such as tetrathiomolybdate ($Mo^{VI}S_4^{2-}$) or Mo^{IV} compounds. Studies conducted in rats have shown that molybdenum is absorbed following exposure to tetrathiomolybdate (Mills et al. 1981a). No quantitative information is available on the toxicokinetics of molybdenum in humans following chronic oral exposure, and there is no information on inhalation or dermal exposures. A study conducted in mice showed that molybdenum is absorbed following inhalation exposure to molybdenum trioxide (NTP 1997).

Studies conducted in humans have provided data for development of PBPK models of molybdenum kinetics in humans (Giussani 2008; Novotny and Turnlund 2007). Models have not been developed for rodents or other animal species that could be used in dosimetry extrapolation of animal bioassay results.

Comparative Toxicokinetics. The available data on the toxicity of molybdenum in humans and laboratory animals suggest that they have similar targets of toxicity; however, there are limited epidemiology data. The available data suggest similarities in the absorption, distribution, and elimination of ingested molybdenum in humans and rats. Additional studies are needed to compare the toxicokinetics of inhaled molybdenum and to assess whether there are species differences.

Methods for Reducing Toxic Effects. No information was identified on methods for reducing toxic effects of molybdenum. Although animal studies provide evidence that a high copper diet may decrease molybdenum toxicity, it is unclear whether this would be effective in humans.

Children's Susceptibility. Data needs relating to both prenatal and childhood exposures, and developmental effects expressed either prenatally or during childhood, are discussed in detail in the Developmental Toxicity subsection above.

There are limited data on the toxicity of molybdenum in children; studies are needed to evaluate whether the susceptibility of children differs from adults.

Child health data needs relating to exposure are discussed in Section 6.8.1, Identification of Data Needs: Exposures of Children.

3.13.3 Ongoing Studies

No ongoing studies on the toxicity of molybdenum or its toxicokinetic properties were identified in the National Institute of Health (NIH) RePORTER (2015) database. The International Molybdenum Association is currently sponsoring a 2-generation reproductive toxicity study in rats orally exposed to sodium molybdate.

4. CHEMICAL AND PHYSICAL INFORMATION

4.1 CHEMICAL IDENTITY

Molybdenum is a naturally occurring trace element that can be found extensively in natural minerals, but not as the free metal. Biologically, it plays an important role as a micronutrient in plants and animals, including humans. It is also used widely in industry for metallurgical applications (EPA 1979).

Molybdenum (Mo) metal exists as a dark-gray or black powder with a metallic luster or as a silvery-white mass (HSDB 2010). It is a member of the group VIb series of the periodic table and can exist in five different oxidation states (2–6), with the most common and stable species being Mo(IV) and Mo(VI) (Barceloux 1999). It does not occur naturally in the pure metallic form, but principally as oxide or sulfide compounds (Barceloux 1999; EPA 1979). Important naturally occurring molybdenum compounds are the minerals molybdenite, powellite, wulfenite, ferrimolybdite, and ilsemannite. Molybdenum anions include molybdate, a tetrahedral poly atomic anion, or other isopolyanions, which can form salts used in industrial applications (EPA 1979). While molybdenum may occur as naturally as molybdenum sulfide, this compound can also be produced synthetically.

Under physiological conditions (pH>6.5), molybdate anion, $[MoO_4]^{2-}$ is the sole molybdenum species in aqueous media (Cruywagen 2000; Cruywagen et al. 2002). Molybdenum compounds (e.g., molybdenum trioxide and polymolybdates) transform rapidly to the $[MoO_4]^{2-}$ ion under environmental relevant test conditions (Deltombe et al. 1974; Greenwood and Earnshaw 1997).

Molybdenum in nature consists of seven stable isotopes (masses 92, 94–98, and 100). Radioisotopes of masses 83–91, 93, 99, and 101–115 have been reported. The only one of major worldwide importance is Mo-99 (^{99}Mo), a 100% beta-emitting isotope with a 65.976-hour radioactive half-life that is used to produce technetium-99m (Tc-99^{m} or ^{99m}Tc) for medical scans (Doll et al. 2014; Parma 2009; Richards 1989).

Information regarding the chemical identity of molybdenum and molybdenum compounds is provided in Table 4-1.

Table 4-1. Chemical Identity of Molybdenum and Compounds[a]

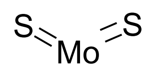
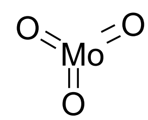
Characteristic	Information		
Chemical name	Molybdenum	Molybdenum disulfide	Molybdenum trioxide
Synonym(s)	Molybdenum metallicum; MChVL; TsM1	Molybdenite (natural mineral); molybdenum(IV) sulfide	Molybdenum(VI) oxide; molybdic acid anhydride; molybdic anhydride; molybdic oxide; molybdena
Registered trade name(s)	Amperit 105.054; Amperit 106.2; Metco 63	DAG 325; Molykote	No data
Chemical formula	Mo	MoS_2	MoO_3
Chemical structure	Mo		
Identification numbers:			
CAS Registry	7439-98-7	1309-56-4 / 1317-33-5 (natural mineral form); 12612-50-9 (synthetic form)	1313-27-5
NIOSH RTECS	QA4680000[b]	QA4697000[b]	No data
EPA Hazardous Waste	No data	No data	No data
OHM/TADS	No data	No data	No data
DOT/UN/NA/IMDG	UN 3089; UN 4.1[c]	No data	UN 3288[c]
HSDB	5032	1660	1661
NCI	No data	No data	No data

Table 4-1. Chemical Identity of Molybdenum and Compounds[a]

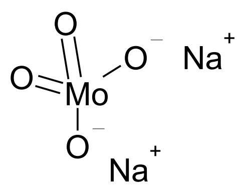
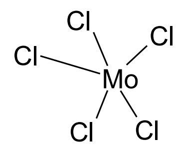
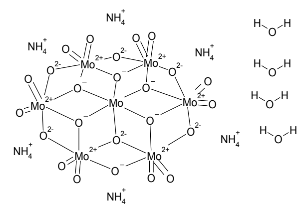
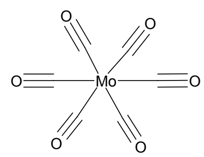
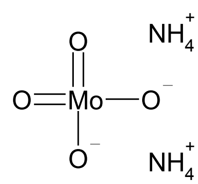
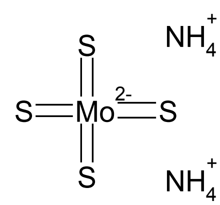
Characteristic	Information		
Chemical name	Sodium molybdate	Molybdenum pentachloride	Ammonium heptamolybdate tetrahydrate
Synonym(s)	Disodium molybdate; molybdic acid, disodium salt	Molybdenum(V) chloride; pentachloromolybdenum	Ammonium paramolybdate tetrahydrate
Registered trade name(s)	No data	No data	No data
Chemical formula	Na_2MoO_4	$MoCl_5$	$(NH_4)_6Mo7O_{24}{\cdot}4H_2O$
Chemical structure			
Identification numbers:			
CAS registry	7631-95-0	10241-05-1	12027-67-7/12054-85-2
NIOSH RTECS	QA5075000[d]	QA4690000[e]	QA5076000[f]
EPA hazardous waste	No data	No data	No data
OHM/TADS	No data	No data	No data
DOT/UN/NA/IMDG shipping	No data	UN 2508[g]	No data
HSDB	7540	No data	7540/1802
NCI	No data	No data	No data

Table 4-1. Chemical Identity of Molybdenum and Compounds[a]

Characteristic	Information		
Chemical name	Molybdenum hexacarbonyl	Diammonium molybdate	Ammonium tetrathiomolybdate
Synonym(s)	Hexacarbonyl-molybdenum; molybdenum(0) hexacarbonyl	Ammonium molybdate; molybdic acid, diammonium salt[g]	Tiomolibdate diammonium; ammonium molybdenum sulfide; thiomolybdic acid, diammonium salt[g]
Registered trade name(s)	No data	No data	Coprexa; TM; ATTM[g]
Chemical formula	$Mo(CO)_6$	$(NH_4)_2MoO_4$	$(NH_4)_2MoS_4$
Chemical structure			
Identification numbers:			
CAS registry	13939-06-5	13106-76-8	15060-55-6
NIOSH RTECS	No data	QA4900000[h]	QA4668250[i]
EPA hazardous waste	No data	No data	No data
OHM/TADS	No data	No data	No data
DOT/UN/NA/IMDG shipping	No data	No data	No data
HSDB	7540	7540	7540
NCI	No data	No data	No data

[a]All information obtained from HSDB (2009a, 2009b, 2009c, 2010) unless otherwise noted.
[b]Sigma-Aldrich 2015e
[c]NOAA 2015
[d]NIOSH 2015c
[e]Sigma-Aldrich 2015a
[f]Sigma-Aldrich 2015b
[g]ChemIDplus 2015
[h]Sigma-Aldrich 2015d
[i]RTECS 2013

CAS = Chemical Abstracts Service; DOT/UN/NA/IMDG = Department of Transportation/United Nations/North America/International Maritime Dangerous Goods Code; EPA = Environmental Protection Agency; HSDB = Hazardous Substances Data Bank; NCI = National Cancer Institute; NIOSH = National Institute for Occupational Safety and Health; OHM/TADS = Oil and Hazardous Materials/Technical Assistance Data System; RTECS = Registry of Toxic Effects of Chemical Substances

4.2 PHYSICAL AND CHEMICAL PROPERTIES

Metallic molybdenum, in the form of dust or powder, is a combustible/flammable solid and is potentially explosive (HSDB 2010).

Information regarding the physical and chemical properties of molybdenum and molybdenum compounds is provided in Table 4-2.

Table 4-2. Physical and Chemical Properties of Molybdenum and Compounds[a]

Property	Information		
Chemical name	Molybdenum	Molybdenite (natural mineral)/molybdenum disulfide	Molybdenum trioxide
Molecular weight	95.94	160.07	143.95
Color	Dark-gray or black	Black	White or slightly yellow or slightly blue
Physical state	Cubic powder	Crystalline solid	Crystalline solid
Melting point	2,622°C	Not applicable	795°C
Boiling point	4,639°C	450°C (sublimes)	1,155°C (sublimes)
Density	10.2 g/cm^3	5.06 (15°C/15°C)	4.69 (26°C/4°C)
Odor	No data	Odorless	Odorless
Odor threshold:			
Water	No data	No data	No data
Air	No data	No data	No data
Solubility:			
Water at 25°C	Insoluble	Insoluble	490 mg/L (28°C)[b]
Organic solvents	Soluble in nitric acid, concentrated sulfuric acid; slightly soluble in hydrochloric acid; insoluble in hydrofluoric acid, dilute sulfuric acid	No data	Insoluble[b]
Inorganic solvents	No data	Soluble in hot sulfuric acid, aqua regia, nitric acid	Soluble in aqueous alkali and ammonia; 140 mg/L in nitric acid (4 mol/L, 20°C)[b]
Partition coefficients:			
Log K_{ow}	No data	No data	No data
Log K_{oc}	No data	No data	No data
Vapor pressure:			
at 20°C	No data	No data	No data
at 2,469°C	7.5x10^{-3} mm Hg	No data	No data
at 2,721°C	7.5x10^{-2} mm Hg	No data	No data
at 3,039°C	0.75 mm Hg	No data	No data
at 3,434°C	7.5 mm Hg	No data	No data
at 3,939°C	75 mm Hg	No data	No data
at 4,606°C	750 mm Hg	No data	No data
Henry's law constant at 25°C	No data	No data	No data
Autoignition temperature	No data	No data	No data
Flashpoint	No data	No data	No data
Flammability limits	Flammable (dust or powder)	No data	Not flammable[c]
Explosive limits	No data	No data	No data
Conversion factors	No data	No data	No data

Table 4-2. Physical and Chemical Properties of Molybdenum and Compounds[a]

Property	Information		
Chemical name	Sodium molybdate	Molybdenum pentachloride	Ammonium heptamolybdate tetrahydrate
Molecular weight	205.92	273.21	1,235.8
Color	White[b]	Dark green-black	Colorless or slightly greenish or yellowish[d]
Physical state	Crystalline solid[e]	Crystalline solid	Crystalline solid[d]
Melting point	687°C[e]	194°C	90°C (loses H_2O)
Boiling point	Not applicable	No data	190°C (decomposes)
Density	3.78 g/cm^3[f]	2.928 g/cm^3[g]	2.86 (20°C)[d]
Odor	Odorless[e]	Odorless[c]	Odorless[e]
Odor threshold:			
Water	No data	No data	No data
Air	No data	No data	No data
Solubility:			
Water	40 wt% (anhydrous salt in 100 g saturated solution, 25°C)[b]	Hydrolyzes	206.5 g/L (20°C, tetrahydrate)[d]
Organic solvents	Soluble in ethanol; very soluble in carbon disulfide[b]	Soluble in carbon tetrachloride, benzene	Soluble in organic solvents[b]
Inorganic solvents	No data	No data	Soluble in aqueous alkali and ammonia; 140 mg/L in HNO_3 (4 mol/L, 20°C)[b]
Partition coefficients:			
Log K_{ow}	No data	No data	No data
Log K_{oc}	No data	No data	0–2.614
Vapor pressure at 20°C	No data	1.75 mm Hg[g]	No data
Henry's law constant at 25°C	No data	No data	No data
Autoignition temperature	No data	No data	No data
Flashpoint	No data	No data	No data
Flammability limits	No data	No data	No data
Explosive limits	No data	No data	No data
Conversion factors	No data	No data	No data

Table 4-2. Physical and Chemical Properties of Molybdenum and Compounds[a]

Property	Information		
Chemical name	Molybdenum hexacarbonyl	Diammonium molybdate	Ammonium tetrathiomolybdate
Molecular weight	264.002	196.01[b]	260.28[b]
Color	White[b]	Colorless, white, or slightly greenish-yellowish[h]	Deep red[b]
Physical state	Crystalline solid	Crystalline solid[b]	Crystalline solid[b]
Melting point	150°C	No data	>300°C[i]
Boiling point	156.4°C (sublimes)[b]	No data	No data
Density	4.692 g/cm^3 (21°C)[b]	1.4[h]	No data
Odor	No data	Odorless[h]	No data
Odor threshold:			
Water	No data	No data	No data
Air	No data	No data	No data
Solubility:			
Water	Insoluble[j]	39 wt% (in 100 g saturated solution, 25°C)[b]	Insoluble (hygroscopic)[k]
Organic solvents	Soluble in most organic solvents[j]	No data	No data
Inorganic solvents	No data	No data	No data
Partition coefficients:			
Log K_{ow}	No data	No data	No data
Log K_{oc}	No data	No data	No data
Vapor pressure at 25°C	9.8 mm Hg (20°C)	No data	No data
Henry's law constant at 25°C	No data	No data	No data
Autoignition temperature	No data	No data	No data
Flashpoint	No data	Not flammable[h]	No data
Flammability limits	No data	Not flammable[h]	No data
Explosive limits	No data	No data	No data
Conversion factors	No data	No data	No data

[a]All information obtained from HSDB (2009a, 2009b, 2009c, 2010) unless otherwise noted.
[b]Sebenik et al. 2012
[c]NOAA 2015
[d]BIAC 2013
[e]ECHA 2015
[f]NIOSH 2015c
[g]Sigma-Aldrich 2015a
[h]NJDOH 2009
[i]Sigma-Aldrich 2015c
[j]Patnaik 1999
[k]Alfa Aesar 2015

5. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.1 PRODUCTION

Molybdenum is a naturally occurring trace element that can be found extensively in nature. Biologically, it plays an important role as a micronutrient in plants and animals, including humans. It is also used widely in industry for metallurgical applications (USGS 2015a).

Molybdenum does not occur naturally in the pure metallic form, but is in minerals principally as oxide or sulfide compounds (Barceloux 1999; EPA 1979). Important naturally occurring molybdenum compounds are the minerals molybdenite (MoS_2, the predominant source), powellite, wulfenite, ferrimolybdate, and ilsemannite. Molybdenum may also form molybdate, a tetrahedral poly atomic anion, or other isopolyanions, which can form salts used in industrial applications. The earth's crust contains an average of 0.0001% (1 ppm) of molybdenum. Deposits that are economically feasible for mining contain ≥200 ppm of molybdenum, with lower concentrations obtained as a byproduct of copper mining (EPA 1979).

Molybdenite (MoS_2) is the principal mineral from which molybdenum is obtained. Mining and milling of crude ore produces molybdenite concentrate containing ≥90% of MoS_2, almost all of which is converted to technical-grade molybdenum trioxide. Molybdenum trioxide is the base material for the production of a variety of chemical compounds, ferromolybdenum, and purified molybdenum (EPA 1979).

Roasting molybdenite concentrate in a multiple hearth furnace at temperatures up to 600°C produces technical-grade molybdenum trioxide. This can be further purified by sublimation or selective recrystallization at about 1,000–1,100°C (EPA 1979).

Worldwide mine production of molybdenum was estimated to be 258,000 mt in 2013, with approximately 92% produced, in descending order, by China, the United States, Chile, Peru, Mexico, and Canada. The United States accounted for 24% of world production with 60,700 mt in 2013, down slightly from 61,500 mt in 2012. Primary molybdenum operations accounted for 53% of total U.S. molybdenum production, while byproduct production made up 47% of the total in 2013. All U.S. molybdenum concentrates and products are from the mining of ore (USGS 2015a). U.S. production of molybdenum increased roughly 8% in 2014 to 65,500 mt (USGS 2015b).

Molybdenum is a chemical that manufacturing and processing facilities would be required to report under Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986 [SARA]) (EPA 1998a). Table 5-1 contains a list the number of facilities per state that produced, processed, or used molybdenum trioxide in 2013, as well as information on the amount of molybdenum on site and related activities and uses (TRI13 2015). Manufacturers are required to report Toxics Release Inventory (TRI) data to satisfy EPA requirements. The TRI data should be used with caution since only certain types of facilities are required to report (EPA 2005b). This is not an exhaustive list.

Molybdenum-99 (^{99}Mo) is a radioactive form of molybdenum and the only molybdenum radioisotope of commercial importance. It is produced in nuclear reactors; then processed, packaged, and shipped to medical facilities throughout the world, where the ^{99}Tc progeny into which it transforms is eluted and injected into patients for imaging purposes (e.g., cardiac stress tests).

^{99}Mo has been being produced in one of eight nuclear reactors (mainly at the Chalk River complex in Canada) using highly enriched uranium, then commercialized at five processing facilities and six generator manufacturing facilities. The availability of those reactors was reduced by the closure of the Chalk River facility, and this has impacted the supply stream. The United States has established a high national priority on assuring an adequate supply of ^{99}Mo and urged manufacturers to switch from using highly enriched uranium (HEU) to low enriched uranium (LEU) to reduce the use of HEU for civilian applications (Ballinger 2010; The White House 2012; USNRC 2015; Van Noorden 2013).

Currently, ^{99}Mo can be produced by placing HEU or LEU targets in an operating nuclear reactor and allowing the neutron flux to produce ^{99}Mo and its radioactive precursors. The quantity of ^{99}Mo peaks after approximately 6 days, at which time, the target is removed, processed, and prepared for shipment. New facilities for producing ^{99}Mo from LEU in the United States are being planned (Welsh et al. 2015).

5.2 IMPORT/EXPORT

Molybdenum-containing exports rose from 49,900 mt in 2010 to 55,300 mt in 2014, while imports for consumption rose from 19,700 mt in 2010 to 23,600 mt in 2014 (USGS 2015b). These data along with U.S. production volumes from 2010 to 2014 are summarized in Table 5-2.

Table 5-1. Facilities that Produced, Processed, or Used Molybdenum Trioxide in 2013

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AL	3	100	99,999	1, 4, 7, 10
AR	1	100,000	999,999	7
AZ	4	100,000	9,999,999	1, 4, 7, 9
CA	14	100	999,999	1, 2, 3, 4, 7, 10, 11, 12
CO	1	10,000	99,999	1, 6, 12, 13
CT	1	100,000	999,999	6
DE	1	100,000	999,999	12
FL	1	1,000	9,999	1, 5, 13
HI	1	100,000	999,999	2, 3, 6, 10
IA	2	1,000,000	9,999,999	1, 3, 4, 7
IL	9	10,000	999,999	1, 5, 6, 7, 10, 11, 12
IN	3	10,000	999,999	1, 5, 7, 10
KS	4	0	999,999	2, 3, 8, 10
KY	4	1,000	999,999	1, 2, 3, 4, 6, 7, 10
LA	19	10,000	9,999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12
MD	1	10,000	99,999	1, 4, 6, 7
ME	1	10,000	99,999	1, 2, 5, 6
MI	3	0	999,999	1, 5, 6, 7, 8, 10, 13
MN	3	10,000	9,999,999	1, 3, 6, 7, 9, 10, 11, 13
MS	3	10,000	999,999	1, 5, 7, 10
MT	2	1,000	99,999	1, 2, 3, 5, 6, 10, 12, 13
ND	3	1,000	99,999	1, 9, 10, 12, 13, 14
NJ	2	100,000	999,999	10
NM	2	10,000	99,999	10
NV	1	10,000	99,999	2, 3, 12
OH	11	1,000	999,999	1, 5, 6, 7, 8, 9, 11, 13
OK	5	10,000	999,999	1, 4, 5, 10, 11, 14
OR	3	1,000	99,999	7, 8
PA	16	100	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13
TN	2	10,000	999,999	6, 7, 9, 10
TX	42	0	99,999,999	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 14
UT	4	100	999,999	10, 11, 12
WA	3	1,000	999,999	7, 11, 12
WI	2	1,000	99,999	1, 5, 7, 11, 14

Table 5-1. Facilities that Produced, Processed, or Used Molybdenum Trioxide in 2013

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
WV	1	1,000,000	9,999,999	2, 3, 7
WY	2	100	999,999	1, 10, 13

[a]Post office state abbreviations used.
[b]Amounts on site reported by facilities in each state.
[c]Activities/Uses:

1. Produce
2. Import
3. Onsite use/processing
4. Sale/Distribution
5. Byproduct
6. Reactant
7. Formulation Component
8. Article Component
9. Repackaging
10. Chemical Processing Aid
11. Manufacturing Aid
12. Ancillary/Other Uses
13. Manufacturing Impurity
14. Process Impurity

Source: TRI13 2015 (Data are from 2013)

Table 5-2. Molybdenum U.S. Production, Import, and Export Data from 2010 to 2014 in Metric Tons

	2010	2011	2012	2013	2014
Total U.S. production	59,400	63,700	61,500	60,700	65,500
U.S. imports for consumption	19,700	21,100	19,800	20,200	23,600
U.S. exports for consumption	49,900	56,700	48,900	53,100	55,300

Source: USGS 2015b

5.3 USE

Molybdenum is used primarily in metallurgical applications, including as an alloying agent in cast iron, steel, and superalloys to enhance properties such as hardenability, strength, toughness, and wear- and corrosion-resistance. Principally in the form of molybdenum trioxide or ferromolybdenum, molybdenum is commonly used in combination with other alloy metals like chromium, manganese, nickel, niobium, and tungsten. The leading form of molybdenum used by industry, particularly in stainless steel production, is molybdenum trioxide (USGS 2015a).

Molybdenum is used significantly as a refractory metal and in a variety of non-metallurgical chemical applications, such as catalysts, lubricants, and pigments. Most molybdenum catalysts are nitrogen deficient due to thermodynamically unfavorable conditions at atmospheric pressure; however, molybdenum nitride was recently produced in a high temperature and pressure environment by solid state ion exchange. Testing found its catalytic activity to be 3 times that of MoS_2 and its selectivity to hydrogenation to be 3 times that of MoS_2 for hydrosulfurizing dibenzothiophene (Wang et al. 2015). As green technology is becoming more popular, molybdenum has become increasingly important in areas like biofuels, catalysts, ethanol, solar panels, and wind power (USGS 2015a).

A radioactive isotope of molybdenum, ^{99}Mo, is used as a source to produce the metastable radioisotope technetium-99m (^{99m}Tc), which is used in the vast majority of medical imaging tests performed today (Doll et al. 2014; Parma 2009; Richards 1989). It was estimated that 85% of all medical radioisotope procedures use ^{99m}Tc and that about 50,000 ^{99m}Tc-based diagnostic procedures are performed in the United States each day, resulting in about 13 million procedures annually (Parma 2009).

Molybdenum concentrate produced by domestic mines is roasted, exported for conversion, or purified to lubricant-grade molybdenum disulfide. Purified MoS_2 is used directly as a solid or in coatings that are bonded onto the metal surface by burnishing, vapor deposition, or bonding processes that use binders, solvents, and mechanochemical procedures (Stiefel 2011).

Metallurgical applications accounted for about 87% of total molybdenum use in 2013. The principle non-metallurgical use was in catalysts, primarily catalysts used in petroleum refining. Molybdenum compounds are also used to produce pigments (USGS 2015a).

5.4 DISPOSAL

Recycling is the most environmentally acceptable means of disposal for stable molybdenum (USGS 2015b). Recovery processes have been developed for the recycling of molybdenum scrap, flue dusts, spent catalysts, and other industrial wastes (HSDB 2010).

Conventional waste water and water treatment methods are unsuccessful in the removal of molybdenum (EPA 1979). Removal of molybdenum in conventional waste water treatment plants averages only 15%. Carbon adsorption raised removal efficiency to about 50%.

Another method for removal of molybdenum from industrial waste streams involves the addition of ferric iron followed by dissolved-air flotation. This technique was shown to have a removal efficiency of 99% (EPA 1979). Milling and mining operations may also use ion exchange technology to treat effluent, which has reported removal efficiencies of about 98% (EPA 1979).

A ^{99m}Tc generator containing a depleted uranium shield or sufficient residual ^{99}Mo radioactivity to be considered radioactive can be disposed of by shipping to an authorized licensee following Nuclear Regulatory Commission agreement state requirements along with those of the Department of Transportation (USNRC 2015). If the ^{99}Mo is allowed to decay sufficiently (typically ≥10 half-lives) and the internal shield is lead or tungsten, then disposal should follow state and local requirements.

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6. POTENTIAL FOR HUMAN EXPOSURE

6.1 OVERVIEW

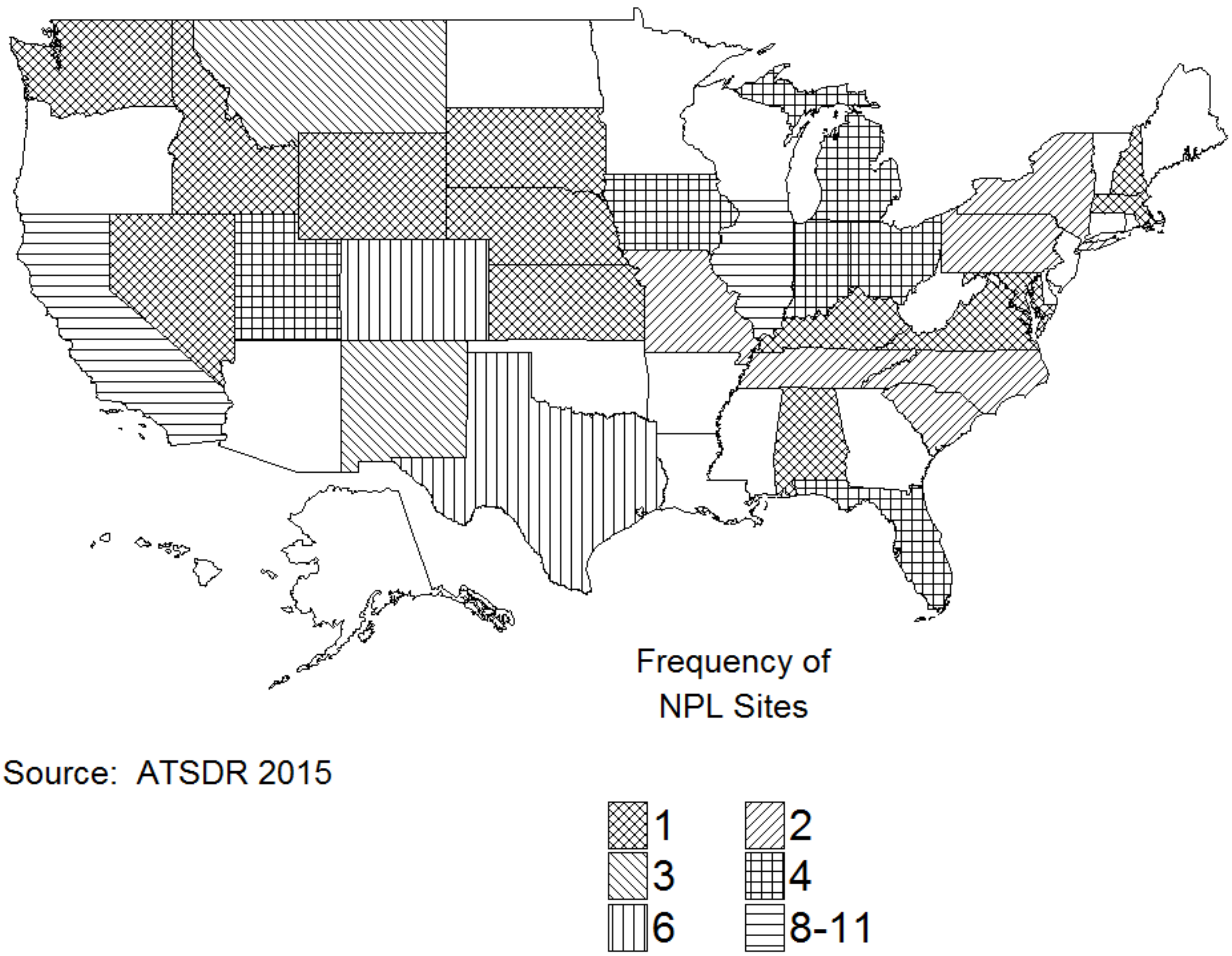
Molybdenum has been identified in at least 86 of the 1,832 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (ATSDR 2015). However, the number of sites in which molybdenum has been evaluated is not known. The frequency of these sites can be seen in Figure 6-1.

Molybdenum is a naturally occurring trace element that can be found extensively in nature. Biologically, molybdenum plays an important role as a micronutrient in plants and animals, including humans. It is also used widely in industry for metallurgical applications (EPA 1979). A radioactive isotope of molybdenum (^{99}Mo) is used as a source for producing metastable technetium-99 (^{99m}Tc), which is an important radiopharmaceutical that is used in the vast majority of high resolution medical imaging tests conducted today (Parma 2009). Important, naturally occurring molybdenum compounds are the minerals molybdenite, powellite, wulfenite, ferrimolybdite, and ilsemannite. Molybdenum may also form molybdate, a tetrahedral polyatomic anion, or other isopolyanions, which can form salts used in industrial applications. The molybdate ion is the most common form of molybdenum found in the aqueous environment (EPA 1979).

If released to the atmosphere, molybdenum will be returned to earth by wet and dry deposition. In water, pH levels and oxidation/reduction conditions of the sediment govern the speciation of molybdenum and adsorption potential in natural aquifers. In the pH range of 3–5, molybdenum tends to exist as hydrogen molybdate and is adsorbed to sediment composed of clay and other oxic minerals (Fitzgerald et al. 2008). The adsorption and mobility of molybdenum in soils is also inversely correlated with pH. Adsorption of molybdenum to 36 surface and subsurface soils was maximized under acidic conditions (pH 2–5) and decreased rapidly at pH 5–8 (Goldberg et al. 2002). The availability of molybdenum to plants and vegetation is also affected by pH and soil properties. Since adsorption to soil decreases with increasing pH, it becomes more bioavailable for uptake to vegetation under nonacidic conditions.

Molybdenum is infrequently detected in ambient air, but is a natural constituent of water and soils. The earth's crust contains an average of 0.0001% (1 ppm) of molybdenum, and surface waters usually have molybdenum concentrations of <5 μg/L (EPA 1979). A decade-long study conducted by the U.S. Geological Survey (USGS) of over 5,000 monitoring and drinking water wells from over 40 major aquifers in the United States reported a median molybdenum concentration of 1 μg/L (USGS 2011).

Figure 6-1. Frequency of NPL Sites with Molybdenum



Source: ATSDR 2015

Anthropogenic activities such as mining operations may result in localized areas where molybdenum levels greatly exceed background levels.

The primary route of exposure for the general population to molybdenum is through the ingestion of food. The National Academy of Sciences (NAS) has estimated that the average dietary intakes (AVDIs) of molybdenum by adult men and women are 109 and 76 μg/day, respectively (NAS 2001). Other routes of exposure, such as inhalation of ambient air, ingestion of drinking water, and dermal exposure, are negligible for the general population; however, they may be important routes of exposure in certain occupational settings such as mining activities and metallurgical applications where molybdenum is used. For example, molybdenum levels in air samples of two plants that produce molybdenum salts were 0.5–200 and 0.2–30 mg/m^3, depending upon the location of the sample and operation being performed (EPA 1979). Respirable dust samples contained molybdenum at levels of 0.471, 1.318, 0.142, and 0.318 mg/m^3 during mining, crushing, milling, and open pit operations, respectively, at a Colorado mine (EPA 1979).

The extensive nationwide use of radioactive ^{99}Mo in generators that produce ^{99m}Tc for nuclear medicine imaging scans can expose medical staff and the public in medical facilities to low levels of ionizing radiation. The extent of those exposures are limited by Nuclear Regulatory Commission and agreement state regulations (USNRC 2016a, 2016b).

6.2 RELEASES TO THE ENVIRONMENT

The Toxics Release Inventory (TRI) data should be used with caution because only certain types of facilities are required to report (EPA 2005). This is not an exhaustive list. Manufacturing and processing facilities are required to report information to the TRI only if they employ 10 or more full-time employees; if their facility is included in Standard Industrial Classification (SIC) Codes 10 (except 1011, 1081, and 1094), 12 (except 1241), 20–39, 4911 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4931 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4939 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4953 (limited to facilities regulated under RCRA Subtitle C, 42 U.S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited to facilities primarily engaged in solvents recovery services on a contract or fee basis); and if their facility produces, imports, or processes ≥25,000 pounds of any TRI chemical or otherwise uses >10,000 pounds of a TRI chemical in a calendar year (EPA 2005).

Molybdenum mining, milling, and smelting, along with its association with uranium mining and milling, copper mining and milling, shale oil production, oil refining, and coal-fired power plants, have resulted in major releases to the environment (EPA 1979).

6.2.1 Air

Estimated releases of 109,063 pounds (~49.5 metric tons) of molybdenum to the atmosphere from 178 domestic manufacturing and processing facilities in 2013 accounted for about 12% of the estimated total environmental releases from facilities required to report to the TRI (TRI13 2015). These releases are summarized in Table 6-1.

The primary source of molybdenum emissions to the atmosphere is coal combustion. In 1970, it was estimated that 550 mt of molybdenum were released via coal combustion in the United States, in comparison to 900 mt estimated from all air pollution sources. A total of 909 mt of molybdenum can be emitted from a single 1,000 megawatt power plant per year (EPA 1979). The concentration of molybdenum in fly ash from coal combustion ranges from 7 to 160 mg/kg (Barceloux 1999).

6.2.2 Water

Estimated releases of 23,474 pounds (~10.6 metric tons) of molybdenum to surface water from 178 domestic manufacturing and processing facilities in 2013 accounted for about 2.6% of the estimated total environmental releases from facilities required to report to the TRI (TRI13 2015). These releases are summarized in Table 6-1.

As a result of secondary treatment processes in publicly owned treatment works (POTWs), up to 85% of molybdenum that enters POTWs can be subsequently released to surface water. This information is available for some chemicals in the open literature.

Per year, it has been estimated that natural processes result in the release of 3.6×10^{10} g of molybdenum into surface waters (EPA 1979).

Aqueous effluents from industries with a high presence of molybdenum, including molybdenum mining, milling, and smelting, uranium mining and milling, copper mining and milling, shale oil production, oil

Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use Molybdenum Trioxide[a]

		Reported amounts released in pounds per year[b]							
							Total release		
State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	On-site[j]	Off-site[k]	On- and off-site
AL	3	2	0	0	43	0	2	43	45
AR	1	7	0	0	188	2,288	7	2,476	2,483
AZ	4	18,002	0	0	149	0	18,002	149	18,151
CA	14	443	42	0	92,870	278	91,967	1,666	93,632
CO	1	3	0	0	0	0	3	0	3
CT	1	688	0	0	0	9,677	688	9,677	10,364
DE	1	14	0	0	0	0	14	0	14
FL	1	255	2,451	0	8,002	0	10,708	0	10,708
HI	1	0	0	0	0	0	0	0	0
IA	2	22,800	3,700	0	250	0	26,750	0	26,750
IL	9	11,400	2,437	0	38,444	3,522	13,837	41,966	55,803
IN	3	280	4,000	0	50,090	2,278	54,282	2,366	56,648
KS	4	250	0	0	10,638	0	255	10,633	10,888
KY	4	1,303	1	0	1,014	174	1,314	1,178	2,492
LA	19	4,797	103	67,073	73,687	374	71,876	74,158	146,033
MD	1	500	1,192	0	250	8,800	1,942	8,800	10,742
ME	1	163	21	0	0	0	184	0	184
MI	3	592	75	0	0	0	667	0	667
MN	3	343	1	0	375	0	344	375	719
MS	3	51	970	0	6,800	0	1,022	6,799	7,821
MT	2	60	240	0	0	93	300	93	393
ND	2	1	0	0	38,053	0	1	38,053	38,054
NJ	2	9	0	0	6,641	0	9	6,641	6,650
NM	2	0	0	0	0	0	0	0	0
NV	1	4	0	0	68,622	0	68,626	0	68,626
OH	11	2,630	280	31,751	5,019	3,975	34,386	9,269	43,655
OK	5	2,386	255	0	52	12,474	2,641	12,526	15,167
OR	3	47	0	0	1,885	0	1,500	432	1,932
PA	16	30,360	648	0	43,710	10,711	32,914	52,515	85,429
TN	2	10	250	0	0	0	260	0	260
TX	41	11,386	6,658	76,400	89,559	76	118,274	65,805	184,079
UT	4	11	0	0	0	0	11	0	11
WA	3	260	0	0	0	0	260	0	260
WI	2	2	150	0	836	0	152	836	988
WV	1	0	0	0	0	0	0	0	0

Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use Molybdenum Trioxide[a]

		Reported amounts released in pounds per year[b]							
							Total release		
State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	On-site[j]	Off-site[k]	On- and off-site
WY	2	5	0	0	16,000	0	16,005	0	16,005
Total	178	109,063	23,474	175,224	553,177	54,719	569,202	346,454	915,657

[a]The TRI data should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Data are rounded to nearest whole number.
[b]Data in TRI are maximum amounts released by each facility.
[c]Post office state abbreviations are used.
[d]Number of reporting facilities.
[e]The sum of fugitive and point source releases are included in releases to air by a given facility.
[f]Surface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).
[g]Class I wells, Class II-V wells, and underground injection.
[h]Resource Conservation and Recovery Act (RCRA) subtitle C landfills; other onsite landfills, land treatment, surface impoundments, other land disposal, other landfills.
[i]Storage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown
[j]The sum of all releases of the chemical to air, land, water, and underground injection wells.
[k]Total amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI13 2015 (Data are from 2013)

refining, and coal-fired power plants, contain molybdenum at concentrations ranging from 100 to 800,000 µg/L (EPA 1979). Molybdenum levels in leachate samples obtained from a landfill located in Caledonia, Wisconsin ranged from 1.28 to 16 µg/L (WDNR 2013).

Effluent concentrations of molybdenum from three molybdenum mining and milling operations (two in Colorado, one in New Mexico) ranged on the order of 1,000–10,000 µg/L. In 1972, a mine in Colorado released approximately 100,000 kg of molybdenum into a receiving stream. Releases of molybdenum from coal power plants to surface waters in the United States average about 1,800 mt/year. A uranium mill in Colorado reported leaking of the tailings ponds containing 860,000 µg/L molybdenum in 1965. Some uranium operations in New Mexico reported as much as 1,000 µg/L molybdenum in aqueous effluents. Copper milling operations have reported molybdenum effluent concentrations as high as 30,000 µg/L (EPA 1979).

6.2.3 Soil

Estimated releases of 553,177 pounds (~251 metric tons) of molybdenum to soils from 178 domestic manufacturing and processing facilities in 2013 accounted for about 58% of the estimated total environmental releases from facilities required to report to the TRI (TRI13 2015). An additional 175,224 pounds (~79 metric tons), constituting about 19% of the total environmental emissions, were released via underground injection (TRI13 2015). These releases are summarized in Table 6-1.

Metals, such as molybdenum, may leach into soil via municipal solid waste incineration bottom ash (IMOA 2015).

6.3 ENVIRONMENTAL FATE

6.3.1 Transport and Partitioning

Molybdenum released to the air by industrial processes will be subject to atmospheric deposition (IMOA 2015). Deposition from the atmosphere is only a minor source to terrestrial and aquatic environments (Fitzgerald et al. 2008).

Molybdenum can be leached into the aquatic environment near industrial use areas via direct release or atmospheric wet deposition by rain (IMOA 2015). The pH of water, along with the composition and redox conditions of the sediment, greatly affect the speciation and adsorption behavior of molybdenum in natural waterbodies. Molybdenum accumulation in the sediment phase is favored under conditions of low pH and in sediments with low redox potential and high iron and organic matter content (Fitzgerald et al. 2008). In more favorable reducing geochemical conditions, solid-phase iron and manganese oxyhydroxides tend to undergo dissolution, and sorbed molybdenum may be released back into the water phase.

In a seasonally anoxic basin, the distribution of molybdenum in the pore water of sediments was relatively uniform. In a perennially oxic basin, however, there was a redistribution of molybdenum in the sediment-water interface subsequent to deposition. This was determined to be a consequence of adsorption of molybdenum to iron oxyhydroxides at a rate of 36 cm^3/molecule-second in the first 1–2 cm depth (IMOA 2015).

Geological uplift and atmospheric deposition result in the molybdenum enrichment of surface soils (IMOA 2015). Molybdenum concentrations are found to be the highest in the top soil layer, due to strong binding to natural organic matter. Goldberg et al. (2002) studied the adsorption potential of molybdenum as a function of pH on 36 surface and subsurface soil samples from 27 soil series belonging to six different soil orders, which provided a wide range of soil physical-chemical characteristics such as organic carbon content, cation exchange capacity, and iron content. In general, maximum adsorption occurred under acidic pH conditions (pH 2–5) and sorption decreased rapidly from pH 5 to 8 and was minimal in all soils at pH >9.

As reviewed by Regolia et al. (2012), the bioaccumulation factor (BAF) ranged from 30.1 to 71.6 (average of 49) in fish exposed to molybdenum levels <65 ug/L. At higher molybdenum levels (up to 766 µg/L), the BAF ranged from 0.4 to 9.9 (average 1.4). A laboratory study in rainbow trout found a similar inverse relationship between molybdenum concentration in the water and bioconcentration factor (BCF) (Regolia et al. 2012). A 60-day exposure to 880 µg/L resulted in tissue levels below the limit of detection. Exposure to 11,100 µg/L for 28 days resulted in whole-body molybdenum levels of 0.53 mg/kg fish; the calculated average BCF was 0.05. In another study, fish in a creek near a molybdenum tailings pile had measured BCFs of <100 after a 2-week exposure (CCME 1999). The molybdenum levels in the liver and kidney were higher than in controls; the molybdenum concentration of the water was not reported. Molybdenum is not expected to bioaccumulate in fish or vegetation.

6.3.2 Transformation and Degradation

As a naturally occurring trace element, molybdenum can be found extensively in nature. The predominant form of molybdenum in natural waters is as the molybdate anion, MoO_4^{-2} (Barceloux 1999), while naturally occurring molybdenum salts are the dominant form in dry environments (EPA 1979).

6.3.2.1 Air

No information regarding the chemical forms of molybdenum in the atmosphere and their transformations could be located. It is generally assumed that metals, especially those from combustion sources, exist in the atmosphere as oxides since metallic species are readily attacked by atmospheric oxidants.

6.3.2.2 Water

Molybdenum in aquatic systems readily forms organometallic complexes. The predominant form of molybdenum in natural waters is as the molybdate anion, MoO_4^{-2} (Barceloux 1999). It can also exist as molybdenum sulfide and bimolybdate (CCME 1999). The molybdate species is most abundant in aquatic environments with pH >7, whereas at pH <7, polymeric species, such as a tetrahedral polyatomic anion or other isopolyanions, may form. At pH <5, molybdenum may also form complexes with excess iron and aluminum (CCME 1999; Cruywagen 2000; Cruywagen et al. 2002).

In low redox environments, the molybdate anion can be reduced to molybdenum disulfide or molybdenite (Fitzgerald et al. 2008).

6.3.2.3 Sediment and Soil

Molybdenum is found naturally in soil as the minerals molybdenite, powellite, wulfenite, ferrimolybdite, and ilsemannite (EPA 1979; Fitzgerald et al. 2008).

The predominant form of molybdenum in wet soil is as the molybdate anion, MoO_4^{-2} (Barceloux 1999).

6.3.2.4 Other Media

No data for the degradation of molybdenum in other media were located.

6.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to molybdenum depends in part on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of molybdenum in unpolluted atmospheres and in pristine surface waters are often so low as to be near the limits of current analytical methods. In reviewing data on molybdenum levels monitored or estimated in the environment, it should also be noted that the amount of chemical identified analytically is not necessarily equivalent to the amount that is bioavailable. The analytical methods available for monitoring molybdenum in a variety of environmental media are detailed in Chapter 7.

6.4.1 Air

Molybdenum concentrations in ambient air have been reported to range from below detection limits to 0.03 mg/m^3 (EPA 1979). Concentrations of molybdenum in ambient air of urban areas, 0.01–0.03 μg/m^3, are higher than those found in rural areas, 0.001–0.0032 μg/m^3 (Barceloux 1999).

6.4.2 Water

It has been reported that concentrations of molybdenum are generally <1.0 μg/L in surface waters (USGS 2006) and 1.0 μg/L in drinking water (USGS 2011). Groundwaters contain about 1.0 μg/L (USGS 2011). It was noted that concentrations >20 μg/L can be attributed to anthropogenic sources, such as mining, upgrading, or other industrial processes (EPA 1979). Near industrial sources, surface water molybdenum concentrations can reach 0.2–0.4 mg/L and groundwater concentrations can reach 25 mg/L (Barceloux 1999). Concentrations as high as 1,400 μg/L have been detected in drinking waters in areas impacted by mining and milling operations, far exceeding the USGS health-based screening level of 40 μg/L (USGS 2011).

A USGS study of surface water from 51 of the nation's major river basins was conducted from 1991 to 2002 (USGS 2006). The median concentration of molybdenum in 2,773 surface water samples was <1.0 μg/L, with a maximum concentration of 157 μg/L. There were eight samples (approximately 0.29% of the total) that exceeded the USGS health-based screening level of 40 μg/L for molybdenum.

In a study of surface waters collected from 197 sampling stations in Colorado, molybdenum was found at concentrations <10 μg/L in 87% of the 299 samples. Samples that contained concentrations >5 μg/L were concluded to be the result of proximity to mineralization or mining and milling operations (EPA

1979). However, another study comparing surface waters draining highly mineralized areas to those with baseline molybdenum areas found that molybdenum mineralization did not contribute significantly to concentrations in surface waters. The waters from streams draining the highly mineralized areas rarely had molybdenum concentrations above 1–2 μg/L (EPA 1979).

DOI (1967) collected river and lake water samples from 100 sampling stations around the United States from 1962 to 1967. The samples were taken from areas susceptible to contamination, including highly populated areas, industrial areas, recreational use areas, and state and national boundaries. Molybdenum was detected in the water samples at maximum concentrations >100 μg/L at 38 of the sample sites, while 26 sites had mean molybdenum concentrations >50 μg/L.

In sea water, the mean molybdenum concentration has been reported as 4–12 μg/L (EPA 1979). Kulathilake and Chatt (1980) reported the molybdenum concentration in the Atlantic Ocean as 7.2–7.9 μg Mo/L. Another study reported that the molybdenum concentration in the North Atlantic ranged from 0.5 to 1.0 μg Mo/L (Chan and Riley 1966). In the Pacific Ocean, measured molybdenum concentrations included 8.8 μg Mo/L in the Eastern Pacific (Kiriyama and Kuroda 1984) and 1.5 μg Mo/L in the Western Pacific (Nakata et al. 1983). Kawabuchi and Kuroda (1969) reported a mean molybdenum concentration of 7.7 μg Mo/L in Tokyo Bay. Molybdenum concentrations measured in the English Channel ranged from 12 to 16 μg Mo/L (Chan and Riley 1966), while the Irish Sea was reported to have a mean molybdenum concentration of 8.4 μg Mo/L (Riley and Taylor 1968).

A comprehensive groundwater monitoring study conducted from 1992 to 2003 by the USGS of 5,183 monitoring and drinking-water wells representative of over 40 principal aquifers in humid and dry regions and in various land-use settings reported that the median concentration of molybdenum in 3,063 samples was 1.0 μg/L, with a maximum value of 4,700 μg/L (USGS 2011). Approximately 1.5% of the groundwater samples had molybdenum levels exceeding the USGS health-based screening level of 40 μg/L (USGS 2011). Levels of molybdenum tended to be greatest in glacial unconsolidated sand and gravel aquifers as compared to other major aquifer groups in the study.

A report issued by the Wisconsin Department of Natural Resources found elevated levels of molybdenum in private supply wells and groundwater monitoring wells near the We Energies Oak Creek power plant located in Caledonia, Wisconsin (WDNR 2013). Molybdenum levels in 21 private well samples exceeded the state of Wisconsin groundwater enforcement standard of 40 μg/L. It was not determined whether the elevated levels of molybdenum were naturally occurring or were a consequence of the activities of the power plant and the coal ash fill areas located nearby the plant.

In a study of finished drinking water supplies from the 100 largest cities in the United States in 1964, median and maximum molybdenum concentrations of 1.4 and 68 μg/L, respectively, were reported (USGS 1964). Another study reported a mean molybdenum concentration of 8 μg/L in samples collected from 161 drinking water sources from 44 states in the United States (Hadjimarkos 1967). Molybdenum levels measured onsite at 12 public water facilities across England and Wales ranged from below the detection limit (0.03 μg/L) to 1.51 μg/L over an 18-month collection period (Smedley et al. 2014). Corresponding molybdenum levels in tap water from 24 residences in three towns (North Wales, the English Midlands, and South East England) served by these public water facilities ranged from <0.03 to 1.00 μg/L. The study indicated that there was little variability in molybdenum concentrations when comparing levels in tap water versus respective water supply facilities, construction ages of the residences (i.e., new homes versus older homes), and pre-flush versus post-flush tap samples, suggesting that water distribution pipework has a negligible effect on supplied tap water levels of molybdenum.

Drinking water may also be affected by industrial contamination, as water treatment facilities are ineffective at removing molybdenum from source waters. In tap waters samples collected in 1971 from Golden, Colorado, a community that derives its water supply from a stream draining a molybdenum mine and mill, the mean molybdenum concentration was reported to be 440 μg/L. However, after the mine closed in 1974, the mean concentration in drinking water samples decreased to 150 μg/L by January 1975, 60 μg/L by June 1975, and 30 μg/L by 1977 (EPA 1979).

6.4.3 Sediment and Soil

Globally, most soils contain molybdenum at concentrations between 0.6 and 3.5 ppm, although total concentrations in soils can vary widely depending on geological composition or industrial contamination. The average concentration of soils is generally 1–2 ppm. In the United States, it has been reported that the median concentration of molybdenum in soils is 1.2–1.3 ppm, with a range of 0.1–40 ppm (EPA 1979). The Forum of European Geological Surveys (FOREGS), under the International Union of Geological Sciences/International Association of Geochemistry (IUGS/IAGC) Global Geochemical Baselines Programme, collected 840 top soil samples from 26 European countries and reported molybdenum concentrations ranging from <0.1 to 21.3 mg/kg (mean 0.943 mg/kg) (FOREGS 2005).

Above average molybdenum soil concentrations may occur in areas containing molybdenum-rich rock formations or in areas of industrial contamination. Natural sources sampled, including soils covering a mineralized area, soil derived from a marine black shale, alluvial soils on the eastern footslopes of Sierra Nevada, and soils formed from volcanic ash in Kauai, Hawaii, contained mean molybdenum concentrations of 76, 12, 17.4, and 14.9 ppm, respectively. Soils sampled near industrial contamination, such as soils downstream from a molybdenum mine and mill in Colorado, soil irrigated with water contaminated by a uranium mill, and soils 2 miles from a molybdenum smelter in Pennsylvania, had mean molybdenum concentrations of 59, 61, and 29 ppm, respectively (EPA 1979).

Typical molybdenum concentrations found in stream sediments were reported to range from 1 to 5 ppm (EPA 1979). Sediments in streams that drain water from natural deposits of molybdenum in the United States have been reported to have molybdenum concentrations ranging from 10 to 200 ppm. Another study reported molybdenum levels of up to 300 ppm in sediments derived from black marine shales in England. Stream sediment collected from water below a molybdenum mine and mill in Colorado had molybdenum concentrations ranging from 50 to 1,800 ppm (mean of 530 ppm). Molybdenum content in stream sediments have been shown to reflect mineralization, as the concentration increases with decreasing sediment grain size (EPA 1979). FOREGS collected 848 freshwater sediment samples from 26 European countries and reported molybdenum concentrations ranging from 0.12 to 117 mg/kg (mean 1.34 mg/kg) (FOREGS 2005).

6.4.4 Other Environmental Media

In a study detecting and comparing trace elements in the milk of guinea pigs (n=87), dairy cattle (n=48), horses (n=35), and humans (n=84), the average molybdenum concentrations measured were 0.026, 0.022, 0.016, and 0.017 ppm, respectively (Anderson 1992). Average concentrations of molybdenum detected in six kinds of milk, including cow's milk-based formula, breast milk, soya milk, bottled milk, dried milk, and evaporated milk, were 18, 4, 160, 34, 35, and 29 μg/L, respectively (Biego et al. 1998). Most of the molybdenum is in the cream fraction (Archibald 1951).

Food derived from aboveground plants, such as legumes, leafy vegetables, and cauliflower generally has a relatively higher concentration of molybdenum in comparison to food from tubers or animals. Beans, cereal grains, leafy vegetables, legumes, liver, and milk are reported as the richest sources of molybdenum in the average diet (Barceloux 1999).

Typical concentrations of molybdenum in plants are 1–2 ppm; however, a range of tenths to hundreds of ppm have been reported (EPA 1979).

Tobacco contains molybdenum concentrations of 0.3–1.76 µg/g (Barceloux 1999).

6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

Molybdenum exposure to the general population via ambient air and drinking water is expected to be negligible compared with exposure through food (Barceloux 1999). Molybdenum does not occur naturally in the pure metallic form. It is principally found as oxide or sulfide compounds (Barceloux 1999; EPA 1979). Therefore, almost all exposure is to a molybdenum compound rather than the metal alone. The average dietary intakes of molybdenum in the United States by adult men and women are 109 and 76 µg/day, respectively (NAS 2001). A study of the dietary intake of adult residents in Denver, Colorado reported a mean molybdenum ingestion rate of 180 µg/day (range 120–240 µg/day) (Barceloux 1999). Daily intake ranged from 74 to 126 µg molybdenum in a study of older children and adults in the Northeastern United States (Barceloux 1999).

The European Food Safety Authority (EFSA) used dietary intake studies to derive estimates of which foods were most responsible for molybdenum intake in European populations (EFSA 2013). Cereals and cereal-based products (including bread) are the largest contributors to molybdenum intake in a Western diet; these products contribute one-third to one-half of the total molybdenum intake. Other contributors to total molybdenum intake include dairy products and vegetables.

A summary of molybdenum concentrations positively identified in foods analyzed during the FDA Total Diet Study (TDS) of 2006–2011 is summarized in Table 6-2 (FDA 2014). The data for molybdenum arose from Market Basket Surveys conducted in 2010 and 2011, in which 382 store-bought foods purchased in four geographic regions of the United States (northeast, southeast, central, and west) were analyzed. Only those food items in which the molybdenum content of at least one sample was above the detection limit of the analytical method are reported. Another survey of levels of molybdenum in food found the highest molybdenum concentrations in legumes; grains and grain products; nuts; meat, fish, and poultry (including liver); eggs; and milk, yogurt, and cheese (76.7, 30.0, 29.5, 8.9, 6.3, and 4.6 µg/100 g, respectively) (Pennington and Jones 1987).

Table 6-2. Molybdenum Levels Detected in Foods in the 2010 and 2011 Market Basket Surveys[a]

Food	Number of samples	Positive detections	Mean (mg/kg)	Median (mg/kg)	Maximum (mg/kg)	LOD (mg/kg)	LOQ (mg/kg)
Liver (beef/calf), pan-cooked with oil	8	8	1.450	1.425	1.660	0.700	3.000
Pinto beans, dry, boiled	8	8	1.320	1.270	1.640	0.700	3.000
Pork and beans, canned	8	1	0.088	0	0.700	0.700	3.000
Peanut butter, smooth/creamy	8	3	0.508	0	1.880	0.900	3.000
Shredded wheat cereal	8	5	0.554	0.883	0.984	0.700	3.000
Raisin bran cereal	8	1	0.088	0	0.701	0.700	3.000
Crisped rice cereal	8	8	0.898	0.837	1.280	0.700	3.000
Granola w/ raisins	8	6	0.589	0.772	0.815	0.700	3.000
Oat ring cereal	8	8	1.260	1.290	1.440	0.700	3.000
Collards, fresh/frozen, boiled	8	2	0.262	0	1.580	0.500	2.000
Chili con carne w/ beans, canned	8	2	0.179	0	0.730	0.700	3.000
Refried beans, canned	8	2	0.254	0	1.100	0.800	3.000
White beans, dry, boiled	8	8	1.137	1.116	1.780	0.700	3.000
Granola bar, w/ raisins	8	1	0.164	0	1.310	0.800	3.000
Candy bar, chocolate, nougat, and nuts	8	1	0.115	0	0.922	0.800	3.000

[a]Trace values were defined as results ≥LOD and <LOQ. Results ≥LOD and <LOQ (trace values) were used as reported when calculating the means.

LOD = limit of detection; LOQ = limit of quantification

Source: FDA 2014

Since molybdenum is biologically essential for good health, it is sometimes necessary for individuals to take vitamins containing molybdenum or dietary molybdenum supplements. Based on data from NHANES, the median molybdenum intake from dietary supplements was about 23 and 24 μg/day for men and women who reported supplement use, respectively. Dietary supplements generally contain molybdenum in the form of sodium molybdate or ammonium molybdate (Momcilovic 1999; NAS 2001).

It was reported in 1979 that in the United States, the average human intake of molybdenum via drinking water was <5 μg/day (EPA 1979). Drinking water coming from sources close to areas with high molybdenum contamination from industrial effluents may contain a higher concentration of molybdenum (>50 μg/L) (EPA 1979).

Urinary levels of molybdenum were measured for the U.S. population from NHANES studies from 1999 to 2012 (CDC 2015). For survey years 1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, and 2011–2012, the geometric mean urinary concentrations of molybdenum were 43.2, 42.5, 39.4, 44.3, 47.1, 45.5, and 42.0 μg/g of creatinine, respectively. The 95th percentile mean concentrations of molybdenum in urine were 144, 130, 120, 132, 137, 143, and 130 μg/g of creatinine in survey years 1999–2000 (sample size 2,257), 2001–2002 (sample size 2,689), 2003–2004 (sample size 2,558), 2005–2006 (sample size 2,576), 2007–2008 (sample size 2,627), 2009–2010 (sample size 2,848), and 2011–2012 (sample size 2,502), respectively (CDC 2015). When the population was divided by age, the geometric mean urinary concentrations (2011–2012 data) were 83.5, 44.4, and 38.6 μg/g creatinine for ages 6–11, 12–19, and ≥20 years, respectively (CDC 2015).

Paschal et al. (1998) analyzed the levels of molybdenum and 12 other metals in the urine of 496 residents of the United States obtained from the NHANES III survey conducted from 1988 to 1994. The specimens randomly selected were from a broad spectrum of the population (e.g., both urban and rural communities, both male and females and persons aged 6–88 years from all major ethnicities). The geometric mean molybdenum concentration of the samples was 46.8 μg/L and the 25th, 50th, 75th, and 95th percentiles were 27.9, 56.5, 93.9, and 168.0, μg/L, respectively. The creatinine-adjusted 25th, 50th, 75th, and 95th percentiles were 30.9, 45.7, 64.3, and 133.8 μg/g, respectively, with a geometric mean of 39.6 μg/g. Urinary molybdenum levels were about 1–2 orders of magnitude greater than any of the other 12 metals analyzed.

Molybdenum levels in whole blood are typically <5 ng/mL in the general population; however, blood samples from persons from areas with natural molybdenum deposits or from molybdenum mining areas may have concentrations of up to 150 μg/mL (Barceloux 1999).

Blood samples collected from 18 miners at a molybdenum mine in New Mexico had plasma molybdenum levels <5 μg/L in 12 of the 18 samples and 6–18 μg/L in the remaining 6 samples. The concentration of molybdenum in urine collected from 11 of the miners ranged from 20 to 74 μg/L. It was noted that molybdenum levels in urine and blood of miners mainly exposed to molybdenite may not be above average, since molybdenite is a relatively insoluble compound (EPA 1979).

In a survey of a molybdenite mining, crushing, and milling operation in Colorado, mean molybdenum levels in respirable dust samples were 0.471, 1.318, 0.142, and 0.318 mg/m^3 during mining, crushing, milling, and open pit operations, respectively (EPA 1979). In settled dust and air samples collected from a molybdenum smelting operation, concentrations of molybdenum, in the form of molybdenum trioxide, were 57–61% and 3–33 mg/m^3, respectively (EPA 1979). Forty air samples collected above a crucible in a molybdenum trioxide smelting plant contained a mean molybdenum concentration of 0.22 mg/m^3, while air samples collected in the breathing zone of workers had molybdenum concentrations ranging from 1.4 to 5.4 mg/m^3 (EPA 1979). The air concentrations of molybdenum in two plants that produce molybdenum salts were 0.5–200 and 0.2–30 mg/m^3 (EPA 1979). More recent monitoring data for mining and milling operations were not located; current levels may be lower due to possible changes in occupational standards, engineering and administrative controls, and personal protective equipment requirements.

Workers involved in metal refining and metal working may be exposed to airborne particulates containing molybdenum. In a study assessing the exposure of a group of 20 workers performing welding, polishing, and assembly of stainless steel constructions, molybdenum was detected in personal air samplers at concentrations of 0.27–9.7, 0.03–4.2, and 0.14–0.60 μg/m^3, respectively. Stationary air samplers in the facility detected course (equivalent aerodynamic diameter [EAD] 2–10 μm) and fine (EAD <2 μm) molybdenum particles at concentrations of 0.015–0.087 and 0.093–0.54 μg/m^3, respectively (Kucera et al. 2000).

The National Occupational Exposure Survey (NOES) conducted by NIOSH in 1983 estimated that 245,024 workers employed at 15,996 facilities were potentially exposed to molybdenum (pure, powder, and unknown forms) in the United States (RTECS 2009). The NOES database does not contain information on the frequency, concentration, or duration of exposure; the survey provides only estimates of workers potentially exposed to chemicals in the workplace.

The extensive nationwide use of radioactive ^{99}Mo in generators that produce ^{99m}Tc for nuclear medicine imaging scans can expose medical staff and the public in medical facilities to low levels of ionizing radiation. The extent of those exposures are limited by the Nuclear Regulatory Commission and agreement state regulations (USNRC 2016a, 2016b).

6.6 EXPOSURES OF CHILDREN

This section focuses on exposures from conception to maturity at 18 years in humans. Differences from adults in susceptibility to hazardous substances are discussed in Section 3.8, Children's Susceptibility.

Children are not small adults. A child's exposure may differ from an adult's exposure in many ways. Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a larger skin surface in proportion to their body volume than adults. A child's diet often differs from that of adults. The developing human's source of nutrition changes with age: from placental nourishment to breast milk or formula to the diet of older children who eat more of certain types of foods than adults. A child's behavior and lifestyle also influence exposure. Children crawl on the floor, put things in their mouths, sometimes eat inappropriate things (such as dirt or paint chips), and may spend more time outdoors. Children also are generally closer to the ground and have not yet developed the adult capacity to judge and take actions to avoid hazards (NRC 1993).

Breast milk and infant formula are the primary sources of molybdenum in infants aged 0–6 months (NAS 2001). The primary source of dietary molybdenum intake among children in the United States is milk (EPA 1979). Several studies have measured molybdenum levels in human breast milk; average molybdenum levels ranged from 1.5 to 17 μg/L (Anderson 1992; Aquilio et al. 1996; Biego et al. 1998; Bougle et al. 1988). As shown in Table 6-3, highest molybdenum concentrations occur within the first week after birth and tend to be higher in the mothers of term infants, as compared to preterm infants (Aquilio et al. 1988; Bougle et al. 1988).

Table 6-3. Molybdenum Levels in Breast Milk in Mothers of Term and Preterm Infants

	Molybdenum levels in breast milk (μg/L)		
Lactation day	Term infants	Preterm infants	Reference
2-6	6.8	3.9[a]	Aquilio et al. 1996
12-16[b]	5.7	2.4[a]	
21[c]	3.6	1.9[a]	
3-5	10.2	4.0[a]	Bougle et al. 1988
7-10[d]	4.8	3.7	
14[d]	1.5	1.4	
30[d]	2.6	1.9	
60[e]	No data	1.2	

[a]Significantly different from term infant levels ($p<0.05$).
[b]Significantly different from molybdenum concentration at 2-6 days ($p<0.01$).
[c]Significantly different from molybdenum concentration at 2-6 days ($p<0.05$).
[d]Significantly different from molybdenum concentration for whole group at 3-5 days ($p<0.01$).
[e]Significantly different from molybdenum concentration at for whole group at 3-5 days ($p<0.05$).

Urinary levels of molybdenum in children 6–11 years old were measured during the NHANES study assessing exposure from 1999 to 2012 (CDC 2015). For survey years 1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, and 2011–2012, the mean urinary concentrations of molybdenum were 85.9, 77.2, 72.5, 81.0, 90.4, 88.6, and 83.5 μg/g of creatinine, respectively. The 95^{th} percentile mean concentrations of molybdenum in urine were 214, 185, 160, 201, 274, 195, and 259 μg/g of creatinine in survey years 1999–2000 (sample size 310), 2001–2002 (sample size 368), 2003–2004 (sample size 290), 2005–2006 (sample size 355), 2007–2008 (sample size 394), 2009–2010 (sample size 378), and 2011–2012 (sample size 398), respectively (CDC 2015).

6.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Workers in an industrial setting such as mining, metal refining, and metal working can be exposed to significant levels of molybdenum (Kucera et al. 2000). Populations living close to areas with high molybdenum contamination from industrial effluents and high mineral deposits are at risk for higher exposures (EPA 1979).

^{99}Mo generators are the major source of ionizing radiation exposure to nuclear medicine staff in medical facilities that perform ^{99m}Tc diagnostic imaging scans (Ahasan 2004).

6.8 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of molybdenum is available. Where adequate information is not available, ATSDR, in conjunction with NTP, is required to assure the initiation of a program of research designed to determine the health effects (and techniques for developing methods to determine such health effects) of molybdenum.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that if met would reduce the uncertainties of human health assessment. This definition should not be interpreted to mean that all data needs discussed in this section must be filled. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

6.8.1 Identification of Data Needs

Physical and Chemical Properties. The physical-chemical properties of molybdenum are provided in Chapter 4. No data needs are identified.

Production, Import/Export, Use, Release, and Disposal. According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit substance release and off-site transfer information to the EPA. The TRI, which contains this information for 2013, became available in October of 2014. This database is updated yearly and should provide a list of industrial production facilities and emissions.

Environmental Fate. Molybdenum is a naturally occurring trace element that can be found extensively in nature (EPA 1979). Its transport and partitioning are well understood. No data needs are identified.

Bioavailability from Environmental Media. Biologically, molybdenum plays an important role as a micronutrient in plants and animals, including humans (EPA 1979). Its bioavailability is well documented. No data needs are identified.

Food Chain Bioaccumulation. Measured BCFs of molybdenum in fish suggest that bioaccumulation in aquatic organisms is not high. No data needs are identified.

Exposure Levels in Environmental Media. Reliable monitoring data for the levels of molybdenum in contaminated media at hazardous waste sites are needed so that the information obtained on levels of molybdenum in the environment can be used in combination with the known body burden of molybdenum to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites.

Exposure Levels in Humans. Exposure to molybdenum to the general population is almost entirely through food. Food derived from aboveground plants, such as legumes, leafy vegetables, and cauliflower generally has a relatively higher concentration of molybdenum in comparison to food from tubers or animals. Beans, cereal grains, leafy vegetables, legumes, liver, and milk are reported as the richest sources of molybdenum in the average diet. Vitamins and nutritional supplements are also a source of dietary exposure. Drinking water coming from sources close to areas with high molybdenum contamination from industrial effluents may contain a higher concentration of molybdenum. Exposure to molybdenum in an industrial setting such as mining can be significant (Barceloux 1999; EPA 1979; Momcilovic 1999; NAS 2001).

This information is necessary for assessing the need to conduct health studies on these populations.

Exposures of Children. There are limited data on estimates of molybdenum exposure in children. Milk is reported to be the primary source of dietary molybdenum intake among children in the United States (Biego et al. 1998; EPA 1979); however, this is based on older data. More recent monitoring data would be valuable in assessing whether molybdenum exposure sources vary between children and adults.

Child health data needs relating to susceptibility are discussed in Section 3.13.2, Identification of Data Needs: Children's Susceptibility.

Exposure Registries. The information amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to exposure to this substance; however, no exposure registries for molybdenum were located. Molybdenum is not currently one of the compounds for which a sub-registry has been established in the National Exposure Registry. Molybdenum will be considered in the future when chemical selection is made for sub-registries to be established.

6.8.2 Ongoing Studies

As part of the National Health and Nutrition Evaluation Survey (NHANES), the Environmental Health Laboratory Sciences Division of the National Center for Environmental Health, Centers for Disease Control and Prevention, will be analyzing human urine samples for molybdenum. These data will give an indication of the frequency of occurrence and background levels of these compounds in a representative sample of the U.S. general population.

7. ANALYTICAL METHODS

The purpose of this chapter is to describe the analytical methods that are available for detecting, measuring, and/or monitoring molybdenum, its metabolites, and other biomarkers of exposure and effect to molybdenum. The intent is not to provide an exhaustive list of analytical methods. Rather, the intention is to identify well-established methods that are used as the standard methods of analysis. Many of the analytical methods used for environmental samples are the methods approved by federal agencies and organizations such as EPA and the National Institute for Occupational Safety and Health (NIOSH). Other methods presented in this chapter are those that are approved by groups such as the Association of Official Analytical Chemists (AOAC) and the American Public Health Association (APHA). Additionally, analytical methods are included that modify previously used methods to obtain lower detection limits and/or to improve accuracy and precision.

7.1 BIOLOGICAL MATERIALS

Table 7-1 lists methods used for determining molybdenum in biological materials. Inductively coupled plasma-mass spectrometry (ICP-MS) is a precise, sensitive, multi-element technique capable of measuring biological fluids (typically urine, blood, or serum) with minimal sample preparation and still achieving sub-μg/L method detection limits. Currently, the most widely used ICP-MS instruments are quadrupole analyzers (Q-ICP-MS), with or without collision or reaction gas technology to remove polyatomic interferences (especially problematic for lower mass isotopes [i.e., below m/z 100, but not typically deemed necessary for molybdenum analysis]). Sector field instruments (SF-ICP-MS) have higher sensitivity compared to Q-ICP-MS and resolve isobaric and polyatomic interferences using physical resolution capabilities, but are typically higher cost than Q-ICP-MS. Inductively coupled plasma optical (atomic) emission spectrometry (ICP-OES/ICP-AES) is, like ICP-MS, a multi-element technique but with higher limits of detection (μg/L). Electrothermal atomic absorption spectrometry (ETAAS) is a widely accepted technique that is less expensive than ICP instruments and capable of detecting μg/L levels of elements in a wide variety of sample types with small (μL) sample sizes. However, ETAAS instruments are more limited in multi-element capabilities than ICP instruments.

ICP analysis coupled with AES is used in NIOSH method 8005 for the determination of molybdenum in blood or tissue (NIOSH 1994a). The detection limits for this method are 1 μg/100 g blood and 0.2 μg/g tissue, which is the average LOD for 20 elements, including molybdenum.

Table 7-1. Analytical Methods for Determining Molybdenum in Biological Samples

Sample matrix[a]	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Human plasma (^{95}Mo, ^{96}Mo isotopes)	Addition of 10 μg vanadium-51. Dried at 35°C, powdered, and compressed. Irradiation of sample with 10 μA proton beam for 6 hours.	PAA/HPGe	2 ng/mL	No data	Cantone et al. 1997
Blood or tissue	Acid digestion with 3:1:1 (v/v/v) nitric, perchloric, and sulfuric acids. Heat.	ICP/AES (NIOSH method 8005)	1 μg/100 g blood; 0.2 μg/g tissue	126% (3.1% RSD at 4.0 μg/ 100 mL blood)	NIOSH 1994a
Blood	Direct injection of 20 μL sample in a ratio 1:2 with 0.1% (v/v) Triton X-100™ to the platform pretreated with Erbium (25 μg).	ETAAS	0.6 μg/L	No data	Burguera et al. 2002
Blood	500 μL of blood diluted 1:10 with 100 μL of 0.1% (v/v) Triton-X-100™, 500 μL of 25 μg/L Tb in 2% (v/v) HNO_3, and 3,900 μL of 0.5% (v/v) NH_4OH.	Q-ICP-MS	0.05 μg/L (LOQ)	103%	Heitland et al. 2006
Blood	1 mL blood microwave digested (23 minutes) with 2 mL concentrated HNO_3 and 1 mL 30% H_2O_2. Digestate diluted 1+9 with 10 μg/L Ga and Y in water.	SF-ICP-MS	0.008 μg/L	No data	Sarmiento-González et al. 2008
Urine	Urine diluted 1+9 with 2% v/v HNO_3, 10 μg/L Ir.	Q-ICP-MS	0.8 μg/L	No data	Caldwell et al. 2005
Urine	Add nitric acid. Adjust pH to 2.0 with 5M NaOH. Extraction with 60 mg polydithiocarbamate resin. Agitate and filter.	ICP/AES (NIOSH method 8310)	0.1 μg/ sample	100%	NIOSH 1994b
Urine	Repeated acid digestion with nitric acid followed by drying.	TIMS	No data	No data	Giussani et al. 1995; 2007
Fecal samples	Homogenize and dry samples followed by acid digestion using nitric acid. Separate from other metals by eluting with hydrochloric acid using an ion exchange column.	TIMS	No data	50%	Turnlund et al. 1993

Table 7-1. Analytical Methods for Determining Molybdenum in Biological Samples

Sample matrix[a]	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Milk	3 g liquid (0.5 mg dried) milk mixed with 3 mL water. Add 4 mL 25% TMAH, 4 mL 5 % w/v Triton X-100™, and 4 mL H_2O_2 (20 volume). Water bath (70°C) for 2 hours with periodic vortexing. Digest diluted to 20 mL with water and 1mL of 400 μg/L Sb. Centrifuged at 5,000 rpm for 5 minutes.	Q-ICP-MS	0.01 μg/g powder	No data	Reid et al. 2008
Milk (mammal)	5 mL homogenized milk wet washed with nitric and perchloric acids (10:1 v/v).	ICP	0.08 ppm	No data	Anderson 1992
Milk (formula, human, soy, bottled, dried, evaporated)	Digestion in microwave oven with 6 mL 65% nitric acid and 1 mL 30% perhydrol. Dilution to a nitric acid concentration of 2%.	ICP/MS	0.9 μg/L	97.8%	Biego et al. 1998

[a]Molybdenum is the target analyte unless otherwise specified.

AES = atomic emission spectrometry; HPGe = high-purity geranium detector; ICP = inductively coupled argon plasma spectroscopy; LOQ = limit of quantification; MS = mass spectrometry; NaOH = sodium hydroxide; NIOSH = National Institute for Occupational Safety and Health; PAA = proton activation analysis; Q-ICP-MS = quadrapole inductively coupled plasma-mass spectrometry; rpm = rotations per minute; RSD = relative standard deviation; SF-ICP-MS = sector field inductively coupled plasma-mass spectrometry; TIMS = thermal ionization mass spectrometry

A method for detecting stable molybdenum isotopes in human blood uses proton activation analysis followed by the measurement of gamma-rays emitted from the activation using a high-purity geranium (HPGe) radiation detector (Cantone et al. 1997). The detection limit for this method was reported to be 2 ng/mL.

NIOSH method 8310 describes a technique for the determination of molybdenum in urine by extraction with a polydithiocarbamate resin. This method uses ICP-AES analysis and has a detection limit of 0.1 µg/sample (NIOSH 1994b).

A method using ICP analysis for the detection of trace elements in homogenized milk has been described (Anderson 1992). The limit of detection was reported as 0.08 ppm. Another method for the detection of molybdenum in various types of milk, including cow's milk-based formula, breast milk, soy milk, bottled milk, dried milk, and evaporated milk was described that uses digestion vessels for sample preparation followed by ICP-MS and has a detection limit of 0.9 µg/L (Biego et al. 1998).

7.2 ENVIRONMENTAL SAMPLES

Table 7-2 lists the methods used for determining molybdenum in environmental samples. Analytical methods determine the total molybdenum content of the samples.

A variety of techniques have been effective in the analytical detection of molybdenum. Emission spectroscopy, x-ray fluorescence, and neutron activation have all been used successfully for aqueous samples; however, these methods are not cost effective. The most widely used analytical methods for the determination of molybdenum in water samples are colorimetric, atomic absorption spectrophotometry (AAS), either flame or graphite furnace (GF), and ICP with AES (EPA 1979; NIOSH 2003a, 2003b, 2003c). Spectral interferences are the primary problems encountered in ICP-AES analysis (NIOSH 2014b).

Molybdenum in air samples can be analyzed using NIOSH methods 7300 and 7301, both of which use acid ashing for sample preparation followed by ICP-AES detection. The limit of detection for these two methods is 0.8 ng/mL of digest or 0.020 µg per filter using either a 5- or 0.45-µm mixed cellulose ester filter with an air volume collection range of 5–67 L of air (NIOSH 2003a, 2003b). NIOSH method 7303 is also used for the analysis of molybdenum in air, but uses hot block digestion instead of acid ashing.

Table 7-2. Analytical Methods for Determining Molybdenum in Environmental Samples

Sample matrix[a]	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Air	Filter collection on 0.8 μm membrane filter. Acid ashing with nitric/perchloric (4:1) acid.	ICP-AES (NIOSH Method 7300)	0.8 ng/mL[b] (800 μg/mL)	105.3% (2.47% RSD at 2.4 ng/mL)	NIOSH 2003a
Air	Filter collection on 0.8 μm membrane filter. Acid ashing with 5% aqua regia (nitric/HCl (1:3)) acid.	ICP-AES (NIOSH Method 7301)	0.8 ng/mL[b] (800 μg/mL)	108.9% (2.7% RSD at 2.4 μg/filter)	NIOSH 2003b
Air	Filter collection on 0.8 μm membrane filter. Hot block digestion at 95°C with 5% HCl and 5% nitric acid.	ICP-AES (NIOSH Method 7303)	0.0072 μg/mL[b]	90–110%	NIOSH 2003c
Occupational dust	Filter collection on 0.8 μm MCE filter. Add 10 mL of 1:1 nitric acid and water. Microwave digestion.	ICP-AES (NIOSH Method 7302)	0.2 μg/sample	96.8% (5.41% RSD at 2.25 μg/sample)	NIOSH 2014a
Dust	Wipe surface, place wipe in beaker, and add 20 mL concentrated nitric acid and 1 mL concentrated perchloric acid and heat.	ICP-AES (NIOSH Method 9102)	0.010 μg/sample	No data	NIOSH 2003d
Dust	Filter collection on 5.0 μm PVC filter. Add 12 mL of 5:1 nitric acid and water. Microwave digestion.	ICP-AES (NIOSH Method 7304)	0.4 μg/sample	87.79% (at 4.5 μg/sample)	NIOSH 2014b
Water	Filter sample through 0.45 μm membrane filter, acidify using nitric acid.	ICP-MS (EPA Method 200.8)	0.01–0.3 μg/L	101%	EPA 1994
Water	Separation and preconcentration with TiO_2 nanoparticles on silica gel. Elution with 0.5 mol/L NaOH.	GF-AAS	0.6 ng/L (600 μg/L)	100% (3.4% RSD at 10 ng/mL)	IMOA 2015
Water	Evaporation to dryness. Pyrolysis and atomization at high temperatures.	GF-AAS (USGS-NWQL I-1492-96)	1 μg/L	No data	USGS 1997
Water and soil	Addition of thiocyanate and MTOAC. Extraction with PBITU in 1-pentanol.	Spectro-photometry	5 ng/mL ($5x10^3$ μg/mL)	No data	IMOA 2015
Water and waste	Extraction by refluxing with nitric and HCl acids.	GF-AAS (EPA-NERL 246.2)	3 μg/L	No data	EPA 1983

Table 7-2. Analytical Methods for Determining Molybdenum in Environmental Samples

Sample matrix[a]	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Hand wipes	Wipe added to 20 mL 4:1 nitric acid/perchloric acid. Heating and drying. Dissolution in 0.5 mL acid mixture.	ICP-AES (NIOSH Method 9102)	0.010 μg/ sample	No data	NIOSH 2003d

[a]Molybdenum is the target analyte unless otherwise specified.
[b]Dectection limit is based on a per mL of acid digest used in the sample preparation procedure.

AAS = atomic absorption spectrophotometry; AES = atomic emission spectroscopy; GF = graphite furnace; EPA = Environmental Protection Agency; HCl = hydrochloric acid; ICP = inductively coupled argon plasma spectroscopy; IMOA = International Molybdenum Association; MCE = mixed cellulose ester membrane; MS = mass spectrometry; MTOAC = methyltrioctyl ammonium chloride; NaOH = sodium hydroxide; NEMI = National Environmental Methods Index; NERL = National Exposure Research Laboratory; NIOSH = National Institute for Occupational Safety and Health; NWQL = National Water Quality Laboratory; PBITU = N-phenylbenzimidoyl thiourea; PVC = polyvinyl chloride; RSD = relative standard deviation; TiO_2 = titanium dioxide; USGS = U.S. Geological Survey

The detection method is also ICP-AES, with a detection limit of 0.0072 µg/mL of digest and a limit of quantification (LOQ) of 0.60 µg/sample with a collection volume range of 0.5–10,000 L of air (NIOSH 2003c).

Methods have also been reported for the detection of molybdenum in metal and nonmetal dust. NIOSH methods 7302 and 7304 use microwave digestion for sample preparation followed by ICP-AES detection (NIOSH 2014). The limits of detection were reported to be 0.2 µg/sample for method 7302 and 0.4 µg/sample for method 7304.

A method for determining trace amounts of molybdenum in water samples separated and preconcentrated with titanium dioxide nanoparticles on silica gel followed by GF-AAS detection has been reported (IMOA 2015). The detection limit is 0.6 ng/L. Two other methods using GF-AAS for the determination of molybdenum in water and waste samples that have detection limits of 1 and 3 µg/L have been described (NEMI 2015).

Molybdenum in environmental samples has been determined using surfactant-mediated liquid-liquid extraction followed by spectrophotometry. The detection limit is 5 ng/mL (IMOA 2015).

NIOSH method 9102 uses ICP-AES for determination of molybdenum on hand wipes and has a detection limit of 0.01 µg/wipe (NIOSH 2003d).

7.3 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of molybdenum is available. Where adequate information is not available, ATSDR, in conjunction with NTP, is required to assure the initiation of a program of research designed to determine the health effects (and techniques for developing methods to determine such health effects) of molybdenum.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that if met would reduce the uncertainties of human health assessment. This definition should not be interpreted to mean that all data needs discussed in this section must be filled. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

7.3.1 Identification of Data Needs

Methods for Determining Biomarkers of Exposure and Effect.

Exposure. Methods for determining background and elevated levels of molybdenum in biological materials are well developed, sensitive, specific, and reliable. Standardized methods are available from NIOSH and other sources.

Effect. No biomarkers of effect were identified.

Methods for Determining Parent Compounds and Degradation Products in Environmental Media. Methods for determining background and elevated levels of molybdenum in environmental media are well-developed, sensitive, and selective. Standardized methods of analysis for molybdenum in air, water, soil, and milk are available from EPA, NIOSH, and other sources. Analytical methods measure total molybdenum.

7.3.2 Ongoing Studies

No ongoing studies were identified in the NIH RePORTER database.

8. REGULATIONS, ADVISORIES, AND GUIDELINES

MRLs are substance specific estimates that are intended to serve as screening levels. They are used by ATSDR health assessors and other responders to identify contaminants and potential health effects that may be of concern at hazardous waste sites.

The international and national regulations, advisories, and guidelines regarding molybdenum in air, water, and other media are summarized in Table 8-1.

A chronic-duration inhalation MRL of 0.0004 mg molybdenum/m^3 was derived for molybdenum. The MRL is based on a $BMCL_{HEC}$ of 0.013 mg molybdenum/m^3 calculated from the incidence data for squamous metaplasia in female mice (NTP 1997) and an uncertainty factor of 30 (3 for extrapolation from animals to humans using dosimetric adjustments and 10 for human variability).

An acute-duration oral MRL of 0.05 mg molybdenum/kg/day was derived based on a NOAEL of 5.3 mg molybdenum/kg/day for increased rate of abnormal MII oocytes in female mice (Zhang et al. 2013) and an uncertainty factor of 100 (10 for extrapolation from animals to humans and 10 for human variability).

An intermediate-duration oral MRL of 0.008 mg molybdenum/kg/day was derived based on a NOAEL of 0.76 mg molybdenum/kg/day for increased estrous cycle length in female rats (Fungwe et al. 1990) and an uncertainty factor of 100 (10 for extrapolation from animals to humans and 10 for human variability).

Table 8-1. Regulations, Advisories, and Guidelines Applicable to Molybdenum

Agency	Description	Information	Reference
<u>INTERNATIONAL</u>			
Guidelines:			
IARC	Carcinogenicity classification	No data	IARC 2015
WHO	Air quality guidelines	No data	WHO 2010
	Drinking water quality guidelines	Not established[a]	WHO 2011
<u>NATIONAL</u>			
Regulations and Guidelines:			
a. Air			
ACGIH	TLV (8-hour TWA)		ACGIH 2015
	Molybdenum (soluble compounds)	0.5 mg/m^3 [b]	
	Molybdenum (Metal and insoluble compounds)	10 mg/m^3 [c]	
		3 mg/m^3 [b]	
AIHA	ERPGs	No data	AIHA 2014
DOE	PACs		DOE 2012a
	PAC-1[d]		
	Molybdenum	10 mg/m^3	
	Molybdenum(IV) sulfide	50 mg/m^3	
	Molybdenum dioxide	1.1 mg/m^3	
	Molybdenum trioxide	0.75 mg/m^3	
	Ammonium molibdate	3.5 mg/m^3	
	Diammonium dimolybdate	2.6 mg/m^3	
	Ammonium molybdate(VI) tetrahydrate	2.8 mg/m^3	
	Disodium molybdate	1.1 mg/m^3	
	Sodium molybdate dihydrate	2.9 mg/m^3	
	Molybdenum carbide	11 mg/m^3	
	Molybdenum pentachloride	4.3 mg/m^3	
	Molybdenum hexacarbonyl	83 mg/m^3	

Table 8-1. Regulations, Advisories, and Guidelines Applicable to Molybdenum

Agency	Description	Information	Reference
NATIONAL (*cont.)*			
DOE (*cont.*)	PACs (*cont.*)		
	PAC-2[d]		
	Molybdenum	10 mg/m^3	
	Molybdenum(IV) sulfide	66 mg/m^3	
	Molybdenum dioxide	1.1 mg/m^3	
	Molybdenum trioxide	0.75 mg/m^3	
	Ammonium molibdate	82 mg/m^3	
	Diammonium dimolybdate	29 mg/m^3	
	Ammonium molybdate(VI) tetrahydrate	11 mg/m^3	
	Disodium molybdate	1.1 mg/m^3	
	Sodium molybdate dihydrate	2.9 mg/m^3	
	Molybdenum carbide	11 mg/m^3	
	Molybdenum pentachloride	150 mg/m^3	
	Molybdenum hexacarbonyl	920 mg/m^3	
	PAC-3[d]		
	Molybdenum	17 mg/m^3	
	Molybdenum(IV) sulfide	400 mg/m^3	
	Molybdenum dioxide	6.9 mg/m^3	
	Molybdenum trioxide	25 mg/m^3	
	Ammonium molibdate	2,700 mg/m^3	
	Diammonium dimolybdate	170 mg/m^3	
	Ammonium molybdate(VI) tetrahydrate	66 mg/m^3	
	Disodium molybdate	230 mg/m^3	
	Sodium molybdate dihydrate	210 mg/m^3	
	Molybdenum carbide	51 mg/m^3	
	Molybdenum pentachloride	880 mg/m^3	
	Molybdenum hexacarbonyl	5500 mg/m^3	
EPA	AEGLs	No data	EPA 2015a
	Hazardous air pollutant	No data	EPA 2013a
NIOSH	REL (up to 10-hour TWA)		NIOSH 2015a, 2015b
	Molybdenum (soluble compounds as Mo)	Not established[e]	
	IDLH		
	Molybdenum (insoluble compounds)	5,000 mg/m^3	
	Molybdenum (soluble compounds)	1,000 mg/m^3	

Table 8-1. Regulations, Advisories, and Guidelines Applicable to Molybdenum

Agency	Description	Information	Reference
NATIONAL (*cont.*)			
OSHA	PEL (8-hour TWA) for general industry, shipyards and construction		OSHA 2013a, 2013b, 2014
	Molybdenum (soluble compounds)	5 mg/m^3	
	Molybdenum (insoluble compounds as Mo; total dust)	15 mg/m^3	
USNRC	Annual limit on intake		NAS 2014
	^{99}Molybdenum compounds except oxides, hydroxides, and molybdenum disulfide	3x10^3 μCi	
	Derived air concentration		
	^{99}Molybdenum compounds except oxides, hydroxides, and molybdenum disulfide	1x10^{-6} μCi/mL	
b. Water			
EPA	Designated as hazardous substances in accordance with Section 311(b)(2)(A) of the Clean Water Act	No data	EPA 2013b 40 CFR 116.4
	Drinking water standards and health advisories for molybdenum		EPA 2012
	1-day health advisory for a 10-kg child	0.08 mg/L	
	10-day health advisory for a 10-kg child	0.08 mg/L	
	DWEL	0.2 mg/L	
	Life-time health advisory	0.04 mg/L	
	National primary drinking water standards	No data	EPA 2009
	National recommended water quality criteria: Human health for the consumption of	No data	EPA 2015b
	Reportable quantities of hazardous substances designated pursuant to Section 311 of the Clean Water Act	No data	EPA 2013c 40 CFR 117.3
c. Food			
FDA	EAFUS	No data[f]	FDA 2013
d. Other			
ACGIH	Carcinogenicity classification		ACGIH 2015
	Molybdenum (soluble compounds)	A3[g]	

Table 8-1. Regulations, Advisories, and Guidelines Applicable to Molybdenum

Agency	Description	Information	Reference
NATIONAL (*cont.)*			
EPA	Carcinogenicity classification	No data	IRIS 2003
	RfC	No data	
	RfD (Molybdenum)	$5x10^{-3}$ mg/kg-day	
	Superfund, emergency planning, and community right-to-know	No data	EPA 2014a 40 CFR 302.4
	Effective date of toxic chemical release reporting		EPA 2014b 40 CFR 372.65
	Molybdenum trioxide	01/01/1987	
	TSCA chemical lists and reporting periods	No data	EPA 2014c 40 CFR 712.30
DHHS	Carcinogenicity classification	No data	NTP 2014

[a]Reason for not establishing a guideline value: occurs in drinking-water at concentrations well below those of health concern.
[b]Respirable fraction; deposited in the gas-exchange region.
[c]Inhalable fraction; deposited anywhere in the respiratory tract.
[d]Definitions of PAC terminology are available from U.S. Department of Energy (DOE 2012b).
[e]A proposed PEL TWA of 5 mg/m^3 for soluble compounds as molybdenum was reviewed by NIOSH in 1988. As a result, NIOSH questioned whether the proposed PEL was adequate to protect workers from recognized health hazards. Additionally, NIOSH also concluded that the documentation cited by OSHA was inadequate to support the proposed PEL (as an 8-hour TWA) of 10 mg/m^3 for insoluble compounds as molybdenum (NIOSH 2015b).
[f]The EAFUS list of substances contains ingredients added directly to food that FDA has either approved as food additives or listed or affirmed as GRAS.
[g]A3: confirmed animal carcinogen with unknown relevance to humans.

ACGIH = American Conference of Governmental Industrial Hygienists; AEGL = acute exposure guideline levels; AIHA = American Industrial Hygiene Association; CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; CFR = Code of Federal Regulations; DHHS = Department of Health and Human Services; DOE = Department of Energy; DWEL = drinking water equivalent level; EAFUS = Everything Added to Food in the United States; EPA = Environmental Protection Agency; ERPG = emergency response planning guidelines; FDA = Food and Drug Administration; GRAS = Generally Recognized As Safe; IARC = International Agency for Research on Cancer; IDLH = immediately dangerous to life or health; IRIS = Integrated Risk Information System; MCL = maximum contaminant level; NAS = National Academy of Sciences; NIOSH = National Institute for Occupational Safety and Health; NTP = National Toxicology Program; OSHA = Occupational Safety and Health Administration; PAC = Protective Action Criteria; PEL = permissible exposure limit; RCRA = Resource Conservation and Recovery Act; REL = recommended exposure limit; RfC = inhalation reference concentration; RfD = oral reference dose; TLV = threshold limit values; TSCA = Toxic Substances Control Act; TWA = time-weighted average; USNRC = U.S. Nuclear Regulatory Commission; WHO = World Health Organization

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10. GLOSSARY

Absorption—The taking up of liquids by solids, or of gases by solids or liquids.

Acute Exposure—Exposure to a chemical for a duration of 14 days or less, as specified in the Toxicological Profiles.

Adsorption—The adhesion in an extremely thin layer of molecules (as of gases, solutes, or liquids) to the surfaces of solid bodies or liquids with which they are in contact.

Adsorption Coefficient (K_{oc})—The ratio of the amount of a chemical adsorbed per unit weight of organic carbon in the soil or sediment to the concentration of the chemical in solution at equilibrium.

Adsorption Ratio (Kd)—The amount of a chemical adsorbed by sediment or soil (i.e., the solid phase) divided by the amount of chemical in the solution phase, which is in equilibrium with the solid phase, at a fixed solid/solution ratio. It is generally expressed in micrograms of chemical sorbed per gram of soil or sediment.

Benchmark Dose (BMD)—Usually defined as the lower confidence limit on the dose that produces a specified magnitude of changes in a specified adverse response. For example, a BMD_{10} would be the dose at the 95% lower confidence limit on a 10% response, and the benchmark response (BMR) would be 10%. The BMD is determined by modeling the dose response curve in the region of the dose response relationship where biologically observable data are feasible.

Benchmark Dose Model—A statistical dose-response model applied to either experimental toxicological or epidemiological data to calculate a BMD.

Bioconcentration Factor (BCF)—The quotient of the concentration of a chemical in aquatic organisms at a specific time or during a discrete time period of exposure divided by the concentration in the surrounding water at the same time or during the same period.

Biomarkers—Broadly defined as indicators signaling events in biologic systems or samples. They have been classified as markers of exposure, markers of effect, and markers of susceptibility.

Cancer Effect Level (CEL)—The lowest dose of chemical in a study, or group of studies, that produces significant increases in the incidence of cancer (or tumors) between the exposed population and its appropriate control.

Carcinogen—A chemical capable of inducing cancer.

Case-Control Study— A type of epidemiological study that examines the relationship between a particular outcome (disease or condition) and a variety of potential causative agents (such as toxic chemicals). In a case-control study, a group of people with a specified and well-defined outcome is identified and compared to a similar group of people without the outcome.

Case Report—Describes a single individual with a particular disease or exposure. These may suggest some potential topics for scientific research, but are not actual research studies.

Case Series—Describes the experience of a small number of individuals with the same disease or exposure. These may suggest potential topics for scientific research, but are not actual research studies.

Ceiling Value—A concentration that must not be exceeded.

Chronic Exposure—Exposure to a chemical for 365 days or more, as specified in the Toxicological Profiles.

Cohort Study—A type of epidemiological study of a specific group or groups of people who have had a common insult (e.g., exposure to an agent suspected of causing disease or a common disease) and are followed forward from exposure to outcome. At least one exposed group is compared to one unexposed group.

Cross-sectional Study—A type of epidemiological study of a group or groups of people that examines the relationship between exposure and outcome to a chemical or to chemicals at one point in time.

Data Needs—Substance-specific informational needs that, if met, would reduce the uncertainties of human health risk assessment.

Developmental Toxicity—The occurrence of adverse effects on the developing organism that may result from exposure to a chemical prior to conception (either parent), during prenatal development, or postnatally to the time of sexual maturation. Adverse developmental effects may be detected at any point in the life span of the organism.

Dose-Response Relationship—The quantitative relationship between the amount of exposure to a toxicant and the incidence of the adverse effects.

Embryotoxicity and Fetotoxicity—Any toxic effect on the conceptus as a result of prenatal exposure to a chemical; the distinguishing feature between the two terms is the stage of development during which the insult occurs. The terms, as used here, include malformations and variations, altered growth, and *in utero* death.

Environmental Protection Agency (EPA) Health Advisory—An estimate of acceptable drinking water levels for a chemical substance based on health effects information. A health advisory is not a legally enforceable federal standard, but serves as technical guidance to assist federal, state, and local officials.

Epidemiology—Refers to the investigation of factors that determine the frequency and distribution of disease or other health-related conditions within a defined human population during a specified period.

Genotoxicity—A specific adverse effect on the genome of living cells that, upon the duplication of affected cells, can be expressed as a mutagenic, clastogenic, or carcinogenic event because of specific alteration of the molecular structure of the genome.

Half-life—A measure of rate for the time required to eliminate one half of a quantity of a chemical from the body or environmental media.

Immediately Dangerous to Life or Health (IDLH)—A condition that poses a threat of life or health, or conditions that pose an immediate threat of severe exposure to contaminants that are likely to have adverse cumulative or delayed effects on health.

Immunologic Toxicity—The occurrence of adverse effects on the immune system that may result from exposure to environmental agents such as chemicals.

Immunological Effects—Functional changes in the immune response.

Incidence—The ratio of new cases of individuals in a population who develop a specified condition to the total number of individuals in that population who could have developed that condition in a specified time period.

Intermediate Exposure—Exposure to a chemical for a duration of 15–364 days, as specified in the Toxicological Profiles.

***In Vitro*—**Isolated from the living organism and artificially maintained, as in a test tube.

***In Vivo*—**Occurring within the living organism.

Lethal Concentration$_{(LO)}$ (LC_{LO})—The lowest concentration of a chemical in air that has been reported to have caused death in humans or animals.

Lethal Concentration$_{(50)}$ (LC_{50})—A calculated concentration of a chemical in air to which exposure for a specific length of time is expected to cause death in 50% of a defined experimental animal population.

Lethal Dose$_{(LO)}$ (LD_{Lo})—The lowest dose of a chemical introduced by a route other than inhalation that has been reported to have caused death in humans or animals.

Lethal Dose$_{(50)}$ (LD_{50})—The dose of a chemical that has been calculated to cause death in 50% of a defined experimental animal population.

Lethal Time$_{(50)}$ (LT_{50})—A calculated period of time within which a specific concentration of a chemical is expected to cause death in 50% of a defined experimental animal population.

Lowest-Observed-Adverse-Effect Level (LOAEL)—The lowest exposure level of chemical in a study, or group of studies, that produces statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control.

Lymphoreticular Effects—Represent morphological effects involving lymphatic tissues such as the lymph nodes, spleen, and thymus.

Malformations—Permanent structural changes that may adversely affect survival, development, or function.

Minimal Risk Level (MRL)—An estimate of daily human exposure to a hazardous substance that is likely to be without an appreciable risk of adverse noncancer health effects over a specified route and duration of exposure.

Modifying Factor (MF)—A value (greater than zero) that is applied to the derivation of a Minimal Risk Level (MRL) to reflect additional concerns about the database that are not covered by the uncertainty factors. The default value for a MF is 1.

Morbidity—State of being diseased; morbidity rate is the incidence or prevalence of disease in a specific population.

Mortality—Death; mortality rate is a measure of the number of deaths in a population during a specified interval of time.

Mutagen—A substance that causes mutations. A mutation is a change in the DNA sequence of a cell's DNA. Mutations can lead to birth defects, miscarriages, or cancer.

Necropsy—The gross examination of the organs and tissues of a dead body to determine the cause of death or pathological conditions.

Neurotoxicity—The occurrence of adverse effects on the nervous system following exposure to a hazardous substance.

No-Observed-Adverse-Effect Level (NOAEL)—The dose of a chemical at which there were no statistically or biologically significant increases in frequency or severity of adverse effects seen between the exposed population and its appropriate control. Effects may be produced at this dose, but they are not considered to be adverse.

Octanol-Water Partition Coefficient (K_{ow})—The equilibrium ratio of the concentrations of a chemical in *n*-octanol and water, in dilute solution.

Odds Ratio (OR)—A means of measuring the association between an exposure (such as toxic substances and a disease or condition) that represents the best estimate of relative risk (risk as a ratio of the incidence among subjects exposed to a particular risk factor divided by the incidence among subjects who were not exposed to the risk factor). An OR of greater than 1 is considered to indicate greater risk of disease in the exposed group compared to the unexposed group.

Organophosphate or Organophosphorus Compound—A phosphorus-containing organic compound and especially a pesticide that acts by inhibiting cholinesterase.

Permissible Exposure Limit (PEL)—An Occupational Safety and Health Administration (OSHA) regulatory limit on the amount or concentration of a substance not to be exceeded in workplace air averaged over any 8-hour work shift of a 40-hour workweek.

Pesticide—General classification of chemicals specifically developed and produced for use in the control of agricultural and public health pests (insects or other organisms harmful to cultivated plants or animals).

Pharmacokinetics—The dynamic behavior of a material in the body, used to predict the fate (disposition) of an exogenous substance in an organism. Utilizing computational techniques, it provides the means of studying the absorption, distribution, metabolism, and excretion of chemicals by the body.

Pharmacokinetic Model—A set of equations that can be used to describe the time course of a parent chemical or metabolite in an animal system. There are two types of pharmacokinetic models: data-based and physiologically-based. A data-based model divides the animal system into a series of compartments, which, in general, do not represent real, identifiable anatomic regions of the body, whereas the physiologically-based model compartments represent real anatomic regions of the body.

Physiologically Based Pharmacodynamic (PBPD) Model—A type of physiologically based dose-response model that quantitatively describes the relationship between target tissue dose and toxic end points. These models advance the importance of physiologically based models in that they clearly describe the biological effect (response) produced by the system following exposure to an exogenous substance.

Physiologically Based Pharmacokinetic (PBPK) Model—Comprised of a series of compartments representing organs or tissue groups with realistic weights and blood flows. These models require a variety of physiological information: tissue volumes, blood flow rates to tissues, cardiac output, alveolar ventilation rates, and possibly membrane permeabilities. The models also utilize biochemical information, such as blood:air partition coefficients, and metabolic parameters. PBPK models are also called biologically based tissue dosimetry models.

Prevalence—The number of cases of a disease or condition in a population at one point in time.

Prospective Study—A type of cohort study in which the pertinent observations are made on events occurring after the start of the study. A group is followed over time.

q_1*—The upper-bound estimate of the low-dose slope of the dose-response curve as determined by the multistage procedure. The q_1* can be used to calculate an estimate of carcinogenic potency, the incremental excess cancer risk per unit of exposure (usually µg/L for water, mg/kg/day for food, and µg/m^3 for air).

Recommended Exposure Limit (REL)—A National Institute for Occupational Safety and Health (NIOSH) time-weighted average (TWA) concentration for up to a 10-hour workday during a 40-hour workweek.

Reference Concentration (RfC)—An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer health effects during a lifetime. The inhalation reference concentration is for continuous inhalation exposures and is appropriately expressed in units of mg/m^3 or ppm.

Reference Dose (RfD)—An estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure of the human population to a potential hazard that is likely to be without risk of deleterious effects during a lifetime. The RfD is operationally derived from the no-observed-adverse-effect level (NOAEL, from animal and human studies) by a consistent application of uncertainty factors that reflect various types of data used to estimate RfDs and an additional modifying factor, which is based on a professional judgment of the entire database on the chemical. The RfDs are not applicable to nonthreshold effects such as cancer.

Reportable Quantity (RQ)—The quantity of a hazardous substance that is considered reportable under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Reportable quantities are (1) 1 pound or greater or (2) for selected substances, an amount established by regulation either under CERCLA or under Section 311 of the Clean Water Act. Quantities are measured over a 24-hour period.

Reproductive Toxicity—The occurrence of adverse effects on the reproductive system that may result from exposure to a hazardous substance. The toxicity may be directed to the reproductive organs and/or the related endocrine system. The manifestation of such toxicity may be noted as alterations in sexual behavior, fertility, pregnancy outcomes, or modifications in other functions that are dependent on the integrity of this system.

Retrospective Study—A type of cohort study based on a group of persons known to have been exposed at some time in the past. Data are collected from routinely recorded events, up to the time the study is undertaken. Retrospective studies are limited to causal factors that can be ascertained from existing records and/or examining survivors of the cohort.

Risk—The possibility or chance that some adverse effect will result from a given exposure to a hazardous substance.

Risk Factor—An aspect of personal behavior or lifestyle, an environmental exposure, existing health condition, or an inborn or inherited characteristic that is associated with an increased occurrence of disease or other health-related event or condition.

Risk Ratio—The ratio of the risk among persons with specific risk factors compared to the risk among persons without risk factors. A risk ratio greater than 1 indicates greater risk of disease in the exposed group compared to the unexposed group.

Short-Term Exposure Limit (STEL)—A STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday.

Standardized Mortality Ratio (SMR)—A ratio of the observed number of deaths and the expected number of deaths in a specific standard population.

Target Organ Toxicity—This term covers a broad range of adverse effects on target organs or physiological systems (e.g., renal, cardiovascular) extending from those arising through a single limited exposure to those assumed over a lifetime of exposure to a chemical.

Teratogen—A chemical that causes structural defects that affect the development of an organism.

Threshold Limit Value (TLV)—An American Conference of Governmental Industrial Hygienists (ACGIH) concentration of a substance to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse effect. The TLV may be expressed as a Time Weighted Average (TLV-TWA), as a Short-Term Exposure Limit (TLV-STEL), or as a ceiling limit (TLV-C).

Time-Weighted Average (TWA)—An average exposure within a given time period.

Toxic Dose$_{(50)}$ (TD_{50})—A calculated dose of a chemical, introduced by a route other than inhalation, which is expected to cause a specific toxic effect in 50% of a defined experimental animal population.

Toxicokinetic—The absorption, distribution, and elimination of toxic compounds in the living organism.

Uncertainty Factor (UF)—A factor used in operationally deriving the Minimal Risk Level (MRL) or Reference Dose (RfD) or Reference Concentration (RfC) from experimental data. UFs are intended to account for (1) the variation in sensitivity among the members of the human population, (2) the uncertainty in extrapolating animal data to the case of human, (3) the uncertainty in extrapolating from data obtained in a study that is of less than lifetime exposure, and (4) the uncertainty in using lowest-observed-adverse-effect level (LOAEL) data rather than no-observed-adverse-effect level (NOAEL) data. A default for each individual UF is 10; if complete certainty in data exists, a value of 1 can be used; however, a reduced UF of 3 may be used on a case-by-case basis, 3 being the approximate logarithmic average of 10 and 1.

Xenobiotic—Any substance that is foreign to the biological system.

APPENDIX A. ATSDR MINIMAL RISK LEVELS AND WORKSHEETS

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [42 U.S.C. 9601 et seq.], as amended by the Superfund Amendments and Reauthorization Act (SARA) [Pub. L. 99–499], requires that the Agency for Toxic Substances and Disease Registry (ATSDR) develop jointly with the U.S. Environmental Protection Agency (EPA), in order of priority, a list of hazardous substances most commonly found at facilities on the CERCLA National Priorities List (NPL); prepare toxicological profiles for each substance included on the priority list of hazardous substances; and assure the initiation of a research program to fill identified data needs associated with the substances.

The toxicological profiles include an examination, summary, and interpretation of available toxicological information and epidemiologic evaluations of a hazardous substance. During the development of toxicological profiles, Minimal Risk Levels (MRLs) are derived when reliable and sufficient data exist to identify the target organ(s) of effect or the most sensitive health effect(s) for a specific duration for a given route of exposure. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified route and duration of exposure. MRLs are based on noncancer health effects only and are not based on a consideration of cancer effects. These substance-specific estimates, which are intended to serve as screening levels, are used by ATSDR health assessors to identify contaminants and potential health effects that may be of concern at hazardous waste sites. It is important to note that MRLs are not intended to define clean-up or action levels.

MRLs are derived for hazardous substances using the no-observed-adverse-effect level/uncertainty factor approach. They are below levels that might cause adverse health effects in the people most sensitive to such chemical-induced effects. MRLs are derived for acute (1–14 days), intermediate (15–364 days), and chronic (365 days and longer) durations and for the oral and inhalation routes of exposure. Currently, MRLs for the dermal route of exposure are not derived because ATSDR has not yet identified a method suitable for this route of exposure. MRLs are generally based on the most sensitive substance-induced endpoint considered to be of relevance to humans. Serious health effects (such as irreparable damage to the liver or kidneys, or birth defects) are not used as a basis for establishing MRLs. Exposure to a level above the MRL does not mean that adverse health effects will occur.

MRLs are intended only to serve as a screening tool to help public health professionals decide where to look more closely. They may also be viewed as a mechanism to identify those hazardous waste sites that are not expected to cause adverse health effects. Most MRLs contain a degree of uncertainty because of the lack of precise toxicological information on the people who might be most sensitive (e.g., infants, elderly, nutritionally or immunologically compromised) to the effects of hazardous substances. ATSDR uses a conservative (i.e., protective) approach to address this uncertainty consistent with the public health principle of prevention. Although human data are preferred, MRLs often must be based on animal studies because relevant human studies are lacking. In the absence of evidence to the contrary, ATSDR assumes that humans are more sensitive to the effects of hazardous substance than animals and that certain persons may be particularly sensitive. Thus, the resulting MRL may be as much as 100-fold below levels that have been shown to be nontoxic in laboratory animals.

Proposed MRLs undergo a rigorous review process: Health Effects/MRL Workgroup reviews within the Division of Toxicology and Human Health Sciences, expert panel peer reviews, and agency-wide MRL Workgroup reviews, with participation from other federal agencies and comments from the public. They are subject to change as new information becomes available concomitant with updating the toxicological profiles. Thus, MRLs in the most recent toxicological profiles supersede previously published levels. For additional information regarding MRLs, please contact the Division of Toxicology and Human Health Sciences, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road NE, Mailstop F-57, Atlanta, Georgia 30329-4027.

MINIMAL RISK LEVEL (MRL) WORKSHEET

Chemical Name: Molybdenum
CAS Numbers: 7439-98-7
Date: April 2017
Profile Status: Final for Public Comment
Route: [X] Inhalation [ ] Oral
Duration: [ ] Acute [ ] Intermediate [X] Chronic
Graph Key: 8
Species: Mouse

Minimal Risk Level: 0.0004 [ ] mg/kg/day [X] mg molybdenum/m^3

Reference: NTP. 1997. Toxicology and carcinogenicity studies of molybdenum trioxide (CAS No. 1313-27-5) in F344/N rats and $B6C3F_1$ mice (inhalation studies). National Toxicology Program, Research Triangle Park, NC. NT PTR 462.

Experimental design: Groups of male and female F344/N rats and B6C3F1 mice (50/sex/species/group) were exposed to target concentrations of 0, 10, 30, or 100 mg/m^3 molybdenum trioxide (0, 6.7, 20, and 67 mg Mo/m^3) 6 hours/day, 5 days/week for 106 (rats) or 105 (mice) weeks; actual concentrations were within 15% of the target level. The average particle sizes (mass median aerodynamic diameter) (and geometric standard deviation) were 1.5 (1.8), 1.6 (1.8), and 1.7 (1.8) μm for the 6.7, 20, and 67 mg/m^3 concentrations, respectively. The following parameters were used to assess toxicity: twice daily cage-side observations, body weights (weekly for 12 weeks, at 15 weeks, monthly thereafter, and at termination), and histopathological examination of major tissues and organs. In addition, bone density and femoral curvature studies were conducted in 10 animals/sex/species/group.

Effect noted in study and corresponding doses: No significant alterations in survival rates or body weight gain and no toxicologically significant alterations in bone density or curvature were found. Non-neoplastic lesions were only observed in the nose, larynx, and lungs; a summary of the type of lesions and incidences is presented in Table A-1. The severity of the respiratory lesions was concentration-related. Significant increases in the incidence of alveolar/bronchiolar carcinoma and/or adenoma were observed in mice: carcinoma in male mice at ≥6.7 mg/m^3, adenoma or carcinoma (combined) in male mice at 6.7 and 20 mg/m^3, adenoma in female mice at ≥20 and 67 mg/m^3, and adenoma or carcinoma (combined) in female mice at 67 mg/m^3. In rats, the incidence of alveolar/bronchiolar adenoma or carcinoma (combined) was increased in males; however, the incidences (0/50, 1/49, 1/49, 4/60) were within the range of historical controls and NTP considered this to be equivocal evidence of carcinogenic activity.

Table A-1. Incidence of Non-Neoplastic Respiratory Tract Lesions in Rats and Mice Exposed to Molybdenum Trioxide for 2 Years

	Concentration (mg molybdenum/m³)			
	0	6.7	20	67
Male rats				
Hyaline degeneration of nasal respiratory epithelium	2/50	7/49	48/49[a]	49/50[a]
Squamous metaplasia of epiglottis	0/49	11/48[a]	16/49[a]	39/49[a]
Chronic lung inflammation in alveolus	2/50	3/50	25/50[a]	47/50[a]
Female rats				
Hyaline degeneration of nasal respiratory epithelium	1/48	13/49[a]	50/50[a]	50/50[a]
Hyaline degeneration of nasal olfactory epithelium	39/48	47/49[b]	50/50[a]	50/50[a]
Squamous metaplasia of epiglottis	0/49	18/49[a]	29/49[a]	49/50[a]
Chronic lung inflammation	14/50	13/50	43/50[a]	49/50[a]
Male mice				
Nasal suppurative inflammation	2/50	6/50	10/49[b]	8/50[b]
Nasal olfactory epithelium atrophy	3/50	5/50	3/49	10/50[b]
Hyaline degeneration of nasal respiratory epithelium	11/50	13/50	11/49	41/50[a]
Squamous metaplasia of epiglottis	0/50	26/49[a]	37/48[a]	49/50[a]
Laryngeal hyperplasia	1/50	3/49	6/48	41/50
Histiocyte infiltration in the lungs	2/50	16/50[a]	9/49[b]	9/50[b]
Alveolar epithelial metaplasia	0/50	32/50[a]	36/49[a]	49/50[a]
Female mice				
Hyaline degeneration of nasal respiratory epithelium	26/49	23/50	28/49	48/49[a]
Hyaline degeneration of nasal olfactory epithelium	22/49	14/50	14/49	36/49[a]
Squamous metaplasia of epiglottis	1/49	36/50[a]	43/49[a]	49/50[a]
Laryngeal hyperplasia	1/49	1/50	7/49	35/50
Alveolar epithelial metaplasia	2/50	26/50[a]	39/49[a]	46/49[b]

[a]Significantly different from controls; $p \leq 0.01$.
[b]Significantly different from controls; $p \leq 0.05$.

Source: NTP 1997

Dose and end point used for MRL derivation: The MRL was based on a BMCL of 0.19 mg molybdenum/m³ for squamous metaplasia of the epiglottis in female mice

[ ] NOAEL [ ] LOAEL [X] BMCL

The incidence data (Table A-1) for respiratory tract lesions, which had significant increases in incidence at ≥6.7 mg/m³ (squamous metaplasia of the epiglottis in male and female rats and mice, hyaline degeneration of the nasal respiratory and olfactory epithelium in female rats, histiocyte infiltration in the lungs in male mice, and alveolar epithelial metaplasia in male and female mice), were fit to all available dichotomous models in EPA's Benchmark Dose Software (BMDS, version 2.4.0) using the extra risk option. Adequate model fit was judged by three criteria: goodness-of-fit statistics (p-value >0.1), visual inspection of the dose-response curve, and scaled residual at the data point (except the control) closest to the predefined BMR. Among all of the models providing adequate fit to the data, the lowest BMCL (95% lower confidence limit on the BMC) was selected as the POD when the difference between the BMCLs estimated from these models was >3-fold; otherwise, the BMCL from the model with the lowest Akaike's Information Criterion (AIC) was chosen. For all lesion types, a BMR of 10% was used. Since the incidence of hyaline degeneration in the olfactory epithelium of female rats was essentially the same response level across groups, the data were not modeled since they provide limited information on the dose-response relationship. The incidence data for histiocyte infiltration in the lungs did not fit any of the available dichotomous models. The model prediction for the other end points are presented in Tables A-2 through A-8 and the fits of the selected models are presented in Figures A-1 through A-7. Although the data for squamous metaplasia of the epiglottis in female mice fit several BMD models, the high incidence in the lowest molybdenum group (72%) decreases the certainty in the modeling results.

Table A-2. Model Predictions for Squamous Metaplasia of the Epiglottis in Male Rats Exposed to Molybdenum Trioxide (NTP 1997)

Model	DF	χ^2	χ^2 Goodness of fit p-value[a]	Scaled residuals[b]: Dose below BMC	Scaled residuals[b]: Dose above BMC	Scaled residuals[b]: Overall largest	AIC	BMC_{10} (mg/m^3)	$BMCL_{10}$ (mg/m^3)
Gamma[c,d]	***3***	***3.07***	***0.38***	***0.00***	***1.55***	***1.55***	***167.98***	***4.36***	***3.53***
Logistic	2	9.63	0.01	1.53	0.95	-2.48	181.94	ND	ND
LogLogistic[e]	2	3.56	0.17	0.00	0.98	-1.42	170.75	3.809	2.23
LogProbit[e]	2	11.85	0.01	3.00	-1.39	3.00	174.85	ND	ND
Multistage (1-degree)[f]	3	3.07	0.38	0.00	1.55	1.55	167.98	4.36	3.53
Multistage (2-degree)[f]	3	3.07	0.38	0.00	1.55	1.55	167.98	4.36	3.53
Multistage (3-degree)[f]	3	3.07	0.38	0.00	1.55	1.55	167.98	4.36	3.53
Probit	2	9.35	0.01	1.62	0.92	-1.38	181.23	ND	ND
Weibull[c]	3	3.07	0.38	0.00	1.55	1.55	167.98	4.36	3.53

[a]Values <0.1 fail to meet conventional goodness-of-fit criteria.
[b]Scaled residuals at doses immediately below and above the BMC; also the largest residual at any dose.
[c]Power restricted to ≥1.
[d]Selected model. BMCLs for models providing adequate fit were sufficiently close (differed by <3-fold). Therefore, the model with the lowest AIC was selected.
[e]Slope restricted to ≥1.
[f]Betas restricted to ≥0.

AIC = Akaike Information Criterion; BMC = maximum likelihood estimate of the exposure concentration associated with the selected benchmark response; BMCL = 95% lower confidence limit on the BMC (subscripts denote benchmark response: i.e., $_{10}$ = exposure concentration associated with 10% extra risk); DF = degrees of freedom; ND = not determined, goodness-of-fit criteria, p<0.10

Figure A-1. Fit of Gamma Model to Data on Incidence of Squamous Metaplasia of the Epiglottis in Male Rats Exposed to Molybdenum Trioxide (mg/m^3)

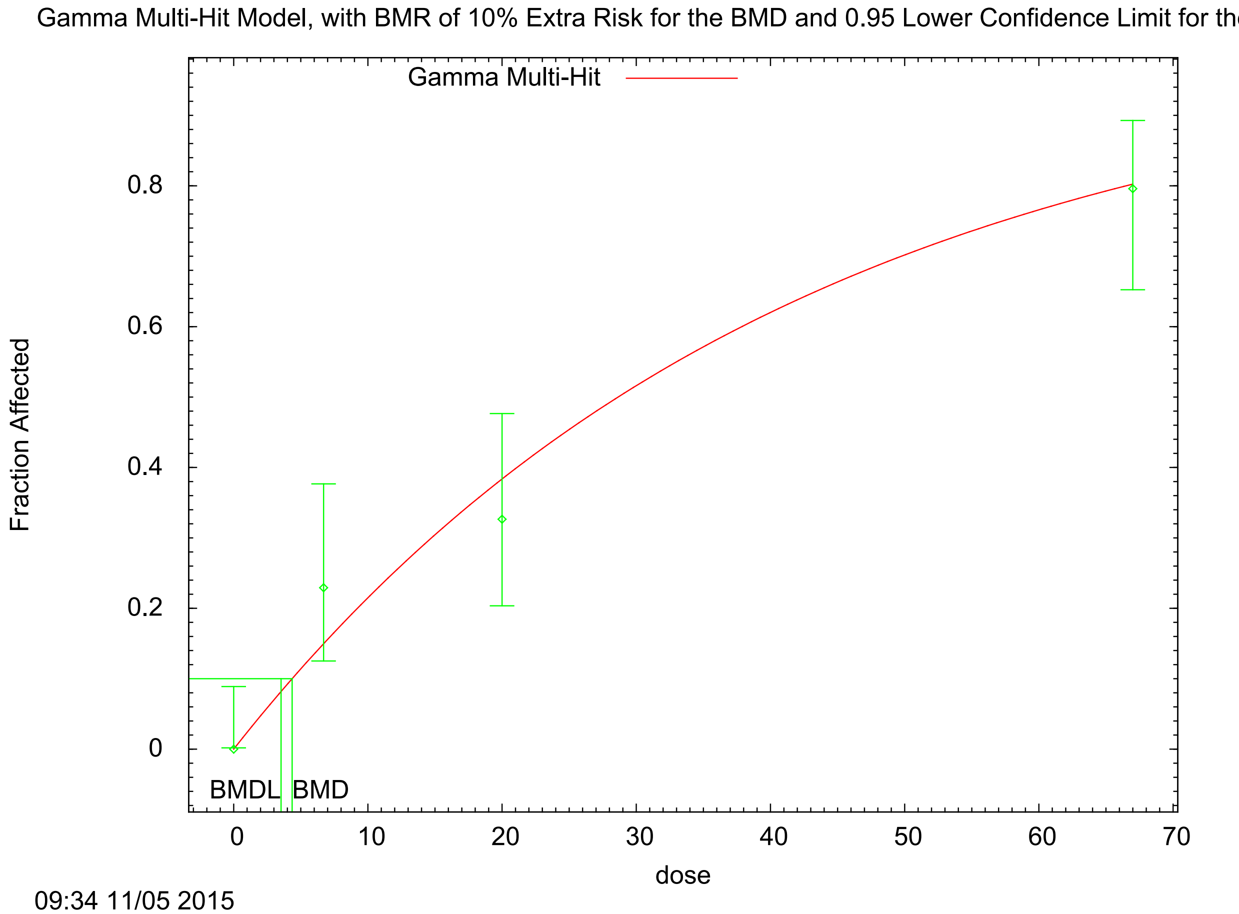


Table A-3. Model Predictions for Hyaline Degeneration of the Nasal Respiratory Epithelium in Female Rats Exposed to Molybdenum Trioxide (NTP 1997)

Model	DF	χ^2	χ^2 Goodness of fit p-value[a]	Scaled residuals[b] Dose below BMC	Dose above BMC	Overall largest	AIC	BMC_{10} (mg/m^3)	$BMCL_{10}$ (mg/m^3)
Gamma[c,d]	***2***	***0.00***	***1.00***	***0.00***	***0.00***	***0.01***	***70.42***	***5.73***	***4.26***
Logistic	2	0.40	0.82	0.44	-0.17	0.44	70.97	4.47	3.46
LogLogistic[e]	2	0.00	1.00	0.00	0.00	0.00	70.42	6.30	4.83
LogProbit[e]	1	0.00	1.00	0.00	0.00	0.00	72.42	6.03	4.73
Multistage (1-degree)[f]	2	18.41	0.00	0.28	-3.28	-3.28	95.80	ND	ND
Multistage (2-degree)[f]	2	2.81	0.24	0.20	-1.21	-1.21	74.57	3.40	2.54
Multistage (3-degree)[f]	2	0.02	0.99	0.01	-0.05	0.15	70.46	4.77	2.39
Probit	2	0.48	0.79	0.49	-0.28	0.49	71.03	4.09	3.12
Weibull[c]	1	0.00	1.00	0.00	0.00	0.00	72.42	5.10	3.58

[a]Values <0.1 fail to meet conventional goodness-of-fit criteria.
[b]Scaled residuals at doses immediately below and above the BMC; also the largest residual at any dose.
[c]Power restricted to ≥1.
[d]Selected model. BMCLs for models providing adequate fit were sufficiently close (differed by <3-fold). Therefore, the model with the lowest AIC was selected.
[e]Slope restricted to ≥1.
[f]Betas restricted to ≥0.

AIC = Akaike Information Criterion; BMC = maximum likelihood estimate of the exposure concentration associated with the selected benchmark response; BMCL = 95% lower confidence limit on the BMC (subscripts denote benchmark response: i.e., $_{10}$ = exposure concentration associated with 10% extra risk); DF = degrees of freedom; ND = not determined, goodness-of-fit criteria, p<0.10

Figure A-2. Fit of Gamma Model to Data on Incidence of Hyaline Degeneration of the Nasal Respiratory Epithelium in Female Rats Exposed to Molybdenum Trioxide (mg/m³)

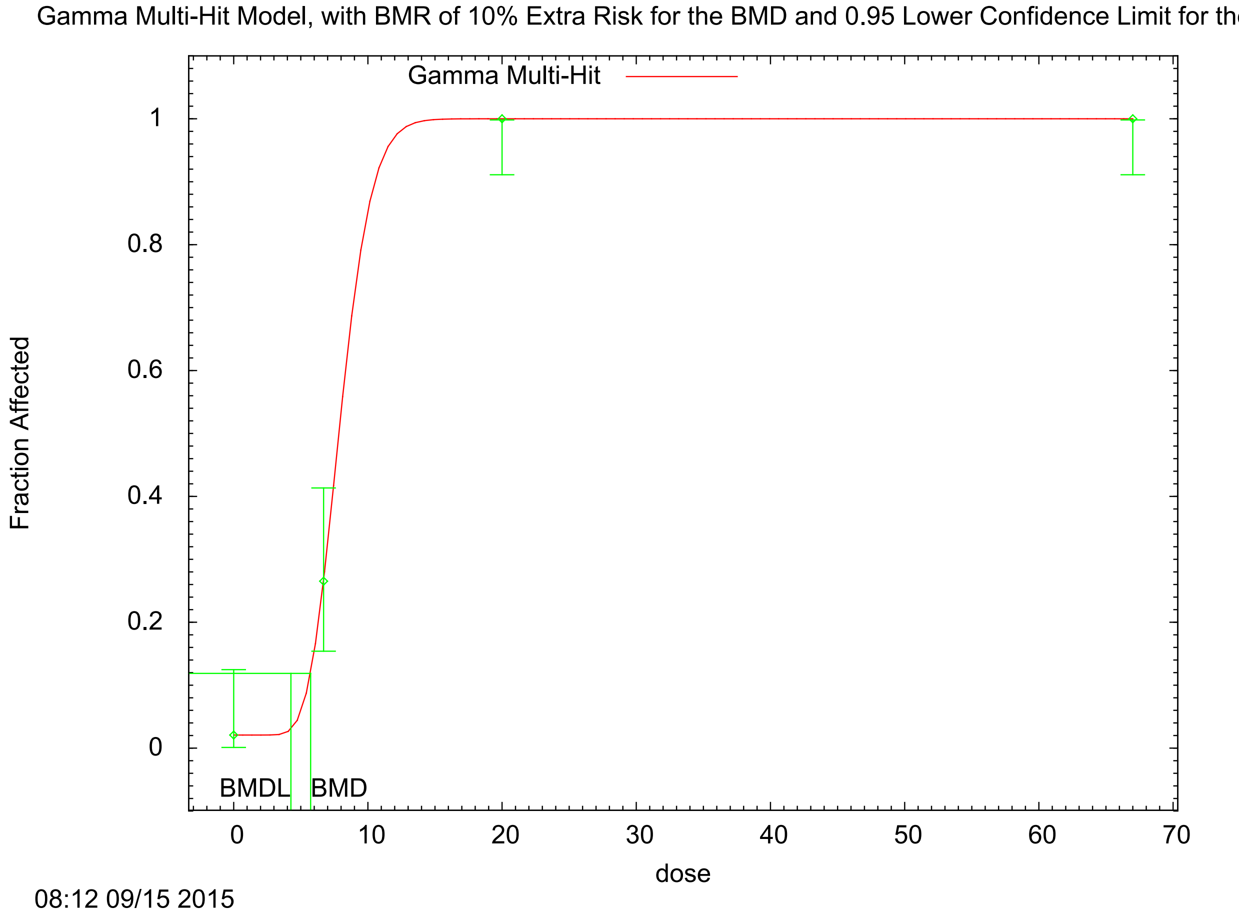


Table A-4. Model Predictions for Squamous Metaplasia of the Epiglottis in Female Rats Exposed to Molybdenum Trioxide (NTP 1997)

Model	DF	χ^2	χ^2 Goodness of fit p-value[a]	Scaled residuals[b] Dose below BMC	Dose above BMC	Overall largest	AIC	BMC_{10} (mg/m^3)	$BMCL_{10}$ (mg/m^3)
Gamma[c,d]	***3***	***2.05***	***0.56***	***0.00***	***1.00***	***1.00***	***144.51***	***1.97***	***1.60***
Logistic	2	15.55	0.00	-2.67	2.17	-2.67	163.85	ND	ND
LogLogistic[e]	2	5.02	0.08	0.00	0.82	-1.58	150.04	ND	ND
LogProbit[e]	3	4.97	0.17	0.00	1.25	-1.69	147.37	3.27	2.67
Multistage (1-degree)[f]	3	2.05	0.56	0.00	1.00	1.00	144.51	1.97	1.60
Multistage (2-degree)[f]	2	2.05	0.36	0.00	1.04	1.04	146.50	1.99	1.60
Multistage (3-degree)[f]	2	1.98	0.37	0.00	1.11	1.11	146.42	2.02	1.61
Probit	2	17.51	0.00	-2.85	2.00	-2.85	166.05	ND	ND
Weibull[c]	3	2.05	0.56	0.00	1.00	1.00	144.51	1.97	1.60

[a]Values <0.1 fail to meet conventional goodness-of-fit criteria.
[b]Scaled residuals at doses immediately below and above the BMC; also the largest residual at any dose.
[c]Power restricted to ≥1.
[d]Selected model. BMCLs for models providing adequate fit were sufficiently close (differed by <3-fold). Therefore, the model with the lowest AIC was selected.
[e]Slope restricted to ≥1.
[f]Betas restricted to ≥0.

AIC = Akaike Information Criterion; BMC = maximum likelihood estimate of the exposure concentration associated with the selected benchmark response; BMCL = 95% lower confidence limit on the BMC (subscripts denote benchmark response: i.e., $_{10}$ = exposure concentration associated with 10% extra risk); DF = degrees of freedom; ND = not determined, goodness-of-fit criteria, p<0.10

Figure A-3. Fit of Gamma Model to Data on Incidence of Squamous Metaplasia of the Epiglottis in Female Rats Exposed to Molybdenum Trioxide (mg/m^3)

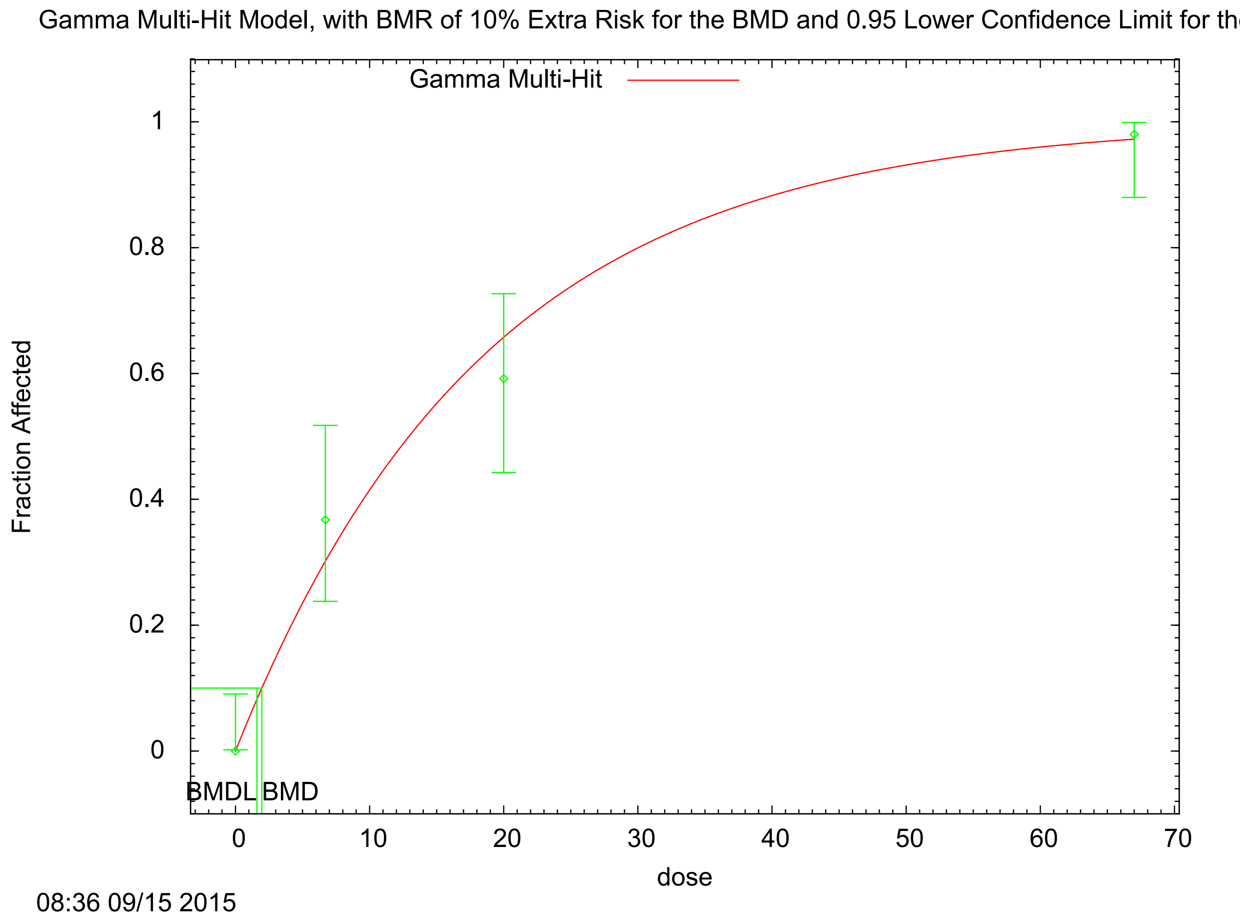


Table A-5. Model Predictions for Squamous Metaplasia of the Epiglottis in Male Mice Exposed to Molybdenum Trioxide (NTP 1997)

Model	DF	χ^2	χ^2 Goodness of fit p-value[a]	Scaled residuals[b] Dose below BMC	Dose above BMC	Overall largest	AIC	BMC_{10} (mg/m^3)	$BMCL_{10}$ (mg/m^3)
Gamma[c]	3	5.55	0.14	0.00	1.60	-1.65	135.46	1.30	1.06
Logistic	2	61.77	0.00	-3.19	2.80	-6.62	164.85	ND	ND
LogLogistic[d,e]	***2***	***1.42***	***0.49***	***0.00***	***0.34***	***-0.85***	***134.73***	***1.29***	***0.47***
LogProbit[d]	3	2.74	0.43	0.00	1.11	1.19	133.83	2.10	1.69
Multistage (1-degree)[f]	3	5.55	0.14	0.00	1.60	-1.65	135.46	1.30	1.06
Multistage (2-degree)[f]	3	5.55	0.14	0.00	1.60	-1.65	135.46	1.30	1.06
Multistage (3-degree)[f]	3	5.55	0.14	0.00	1.60	-1.65	135.46	1.30	1.06
Probit	2	90.03	0.00	-3.63	2.65	-8.24	171.89	ND	ND
Weibull[c]	3	5.55	0.14	0.00	1.60	-1.65	135.46	1.30	1.06

[a]Values <0.1 fail to meet conventional goodness-of-fit criteria.
[b]Scaled residuals at doses immediately below and above the BMC; also the largest residual at any dose.
[c]Power restricted to ≥1.
[d]Slope restricted to ≥1.
[e]Selected model. BMCLs for models providing adequate fit were sufficiently close (differed by <3-fold). Therefore, the model with the lowest AIC was selected.
[f]Betas restricted to ≥0.

AIC = Akaike Information Criterion; BMC = maximum likelihood estimate of the exposure concentration associated with the selected benchmark response; BMCL = 95% lower confidence limit on the BMC (subscripts denote benchmark response: i.e., $_{10}$ = exposure concentration associated with 10% extra risk); DF = degrees of freedom; ND = not determined, goodness-of-fit criteria, p<0.10

Figure A-4. Fit of LogLogistic Model to Data on Incidence of Squamous Metaplasia of the Epiglottis in Male Mice Exposed to Molybdenum Trioxide (mg/m³)

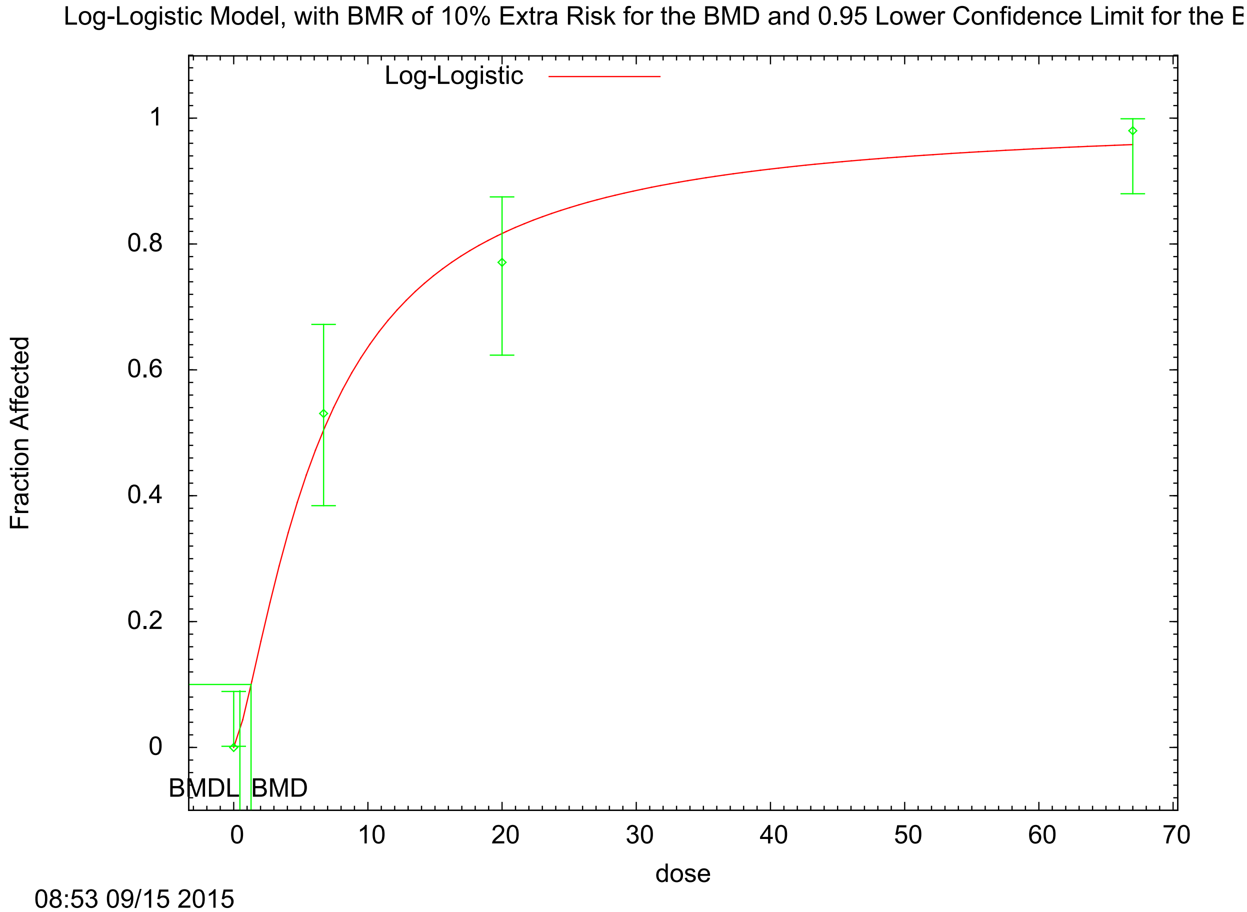


Table A-6. Model Predictions for Alveolar Epithelial Metaplasia in Male Mice Exposed to Molybdenum Trioxide (NTP 1997)

Model	DF	χ^2	χ^2 Goodness of fit p-value[a]	Scaled residuals[b] Dose below BMC	Dose above BMC	Overall largest	AIC	BMC_{10} (mg/m^3)	$BMCL_{10}$ (mg/m^3)
Gamma[c]	3	15.12	0.00	0.00	2.91	2.91	146.34	ND	ND
Logistic	2	44.97	0.00	-3.71	3.74	-4.41	177.74	ND	ND
LogLogistic[d,e]	***2***	***4.20***	***0.12***	***0.00***	***0.63***	***-1.55***	***140.27***	***0.54***	***0.35***
LogProbit[d]	3	10.82	0.01	0.00	2.15	-2.43	143.68	ND	ND
Multistage (1-degree)[f]	3	15.12	0.00	0.00	2.91	2.91	146.34	ND	ND
Multistage (2-degree)[f]	3	15.12	0.00	0.00	2.91	2.91	146.34	ND	ND
Multistage (3-degree)[f]	3	15.12	0.00	0.00	2.91	2.91	146.34	ND	ND
Probit	2	54.33	0.00	-4.10	3.67	-4.84	183.04	ND	ND
Weibull[c]	3	15.12	0.00	0.00	2.91	2.91	146.34	ND	ND

[a]Values <0.1 fail to meet conventional goodness-of-fit criteria.
[b]Scaled residuals at doses immediately below and above the BMC; also the largest residual at any dose.
[c]Power restricted to ≥1.
[d]Slope restricted to ≥1.
[e]Selected model. The only model that provided adequate fit to the data was the Log-Logistic model.
[f]Betas restricted to ≥0.

AIC = Akaike Information Criterion; BMC = maximum likelihood estimate of the exposure concentration associated with the selected benchmark response; BMCL = 95% lower confidence limit on the BMC (subscripts denote benchmark response: i.e., $_{10}$ = exposure concentration associated with 10% extra risk); DF = degrees of freedom; ND = not determined, goodness-of-fit criteria, p<0.10

Figure A-5. Fit of LogLogistic Model to Data on Incidence of Alveolar Epithelial Metaplasia in Male Mice Exposed to Molybdenum Trioxide (mg/m^3)

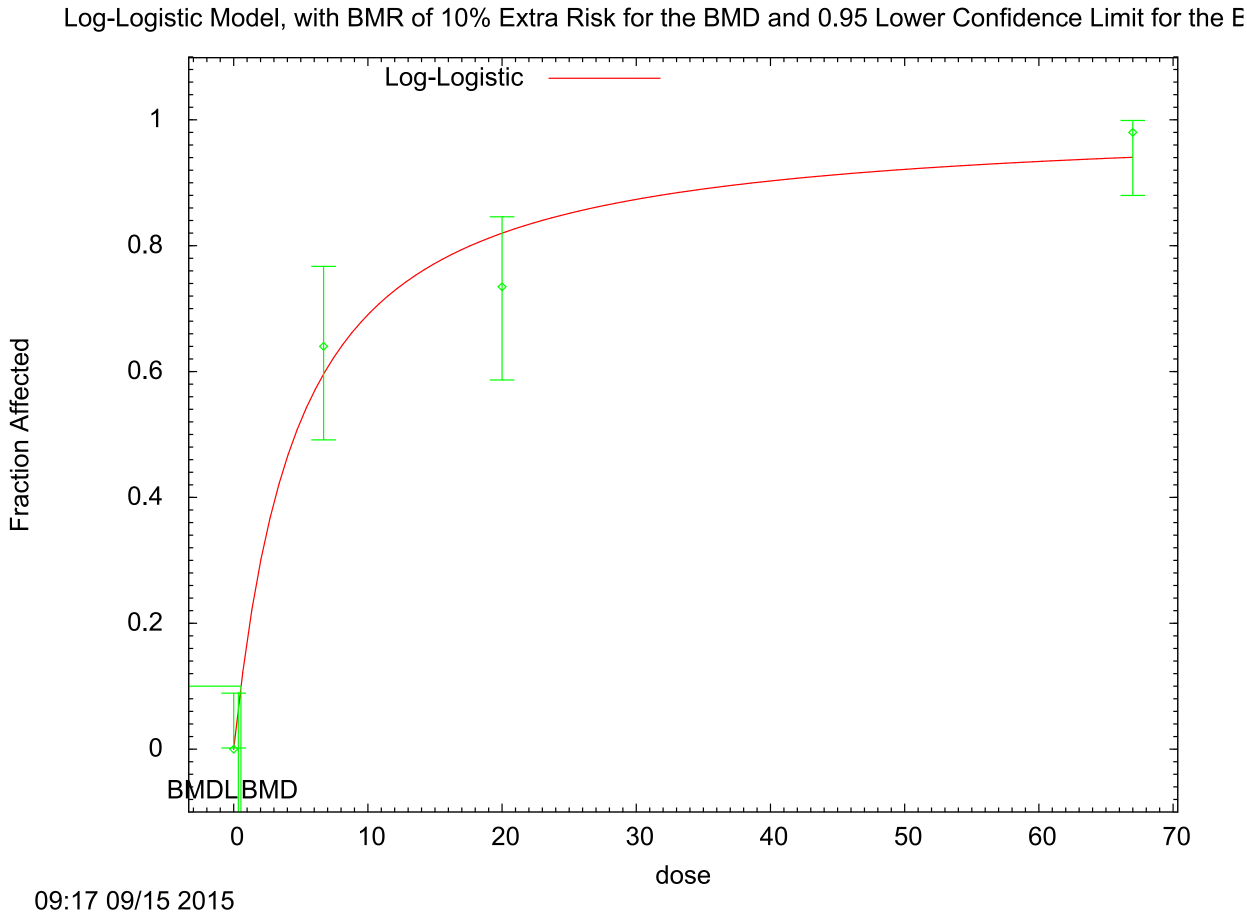


Table A-7. Model Predictions for Squamous Metaplasia of the Epiglottis in Female Mice Exposed to Molybdenum Trioxide (NTP 1997)

Model	DF	χ^2	χ^2 Goodness of fit p-value[a]	Scaled residuals[b] Dose below BMC	Dose above BMC	Overall largest	AIC	BMC_{10} (mg/m^3)	$BMCL_{10}$ (mg/m^3)
Gamma[c]	2	57.98	0.00	-0.29	2.32	-7.21	131.51	ND	ND
Logistic	2	413.85	0.00	-3.51	3.42	-19.74	159.94	ND	ND
LogLogistic[d,e]	***1***	***0.32***	***0.57***	***0.00***	***0.15***	***-0.41***	***121.62***	***0.46***	***0.19***
LogProbit[d]	2	5.96	0.05	-0.08	1.26	-1.71	123.72	ND	ND
Multistage (1-degree)[f]	2	57.98	0.00	-0.29	2.32	-7.21	131.51	ND	ND
Multistage (2-degree)[f]	2	57.98	0.00	-0.29	2.32	-7.21	131.51	ND	ND
Multistage (3-degree)[f]	2	57.98	0.00	-0.29	2.32	-7.21	131.51	ND	ND
Probit	2	511.74	0.00	-4.31	3.51	-21.88	172.08	ND	ND
Weibull[c]	2	57.98	0.00	-0.29	2.32	-7.21	131.51	ND	ND

[a]Values <0.1 fail to meet conventional goodness-of-fit criteria.
[b]Scaled residuals at doses immediately below and above the BMC; also the largest residual at any dose.
[c]Power restricted to ≥1.
[d]Slope restricted to ≥1.
[e]Selected model. The only model that provided adequate fit to the data was the Log-Logistic model.
[f]Betas restricted to ≥0.

AIC = Akaike Information Criterion; BMC = maximum likelihood estimate of the exposure concentration associated with the selected benchmark response; BMCL = 95% lower confidence limit on the BMC (subscripts denote benchmark response: i.e., $_{10}$ = exposure concentration associated with 10% extra risk); DF = degrees of freedom; ND = not determined, goodness-of-fit criteria, p<0.10

Figure A-6. Fit of LogLogistic Model to Data on Incidence of Squamous Metaplasia of the Epiglottis in Female Mice Exposed to Molybdenum Trioxide (mg/m³)

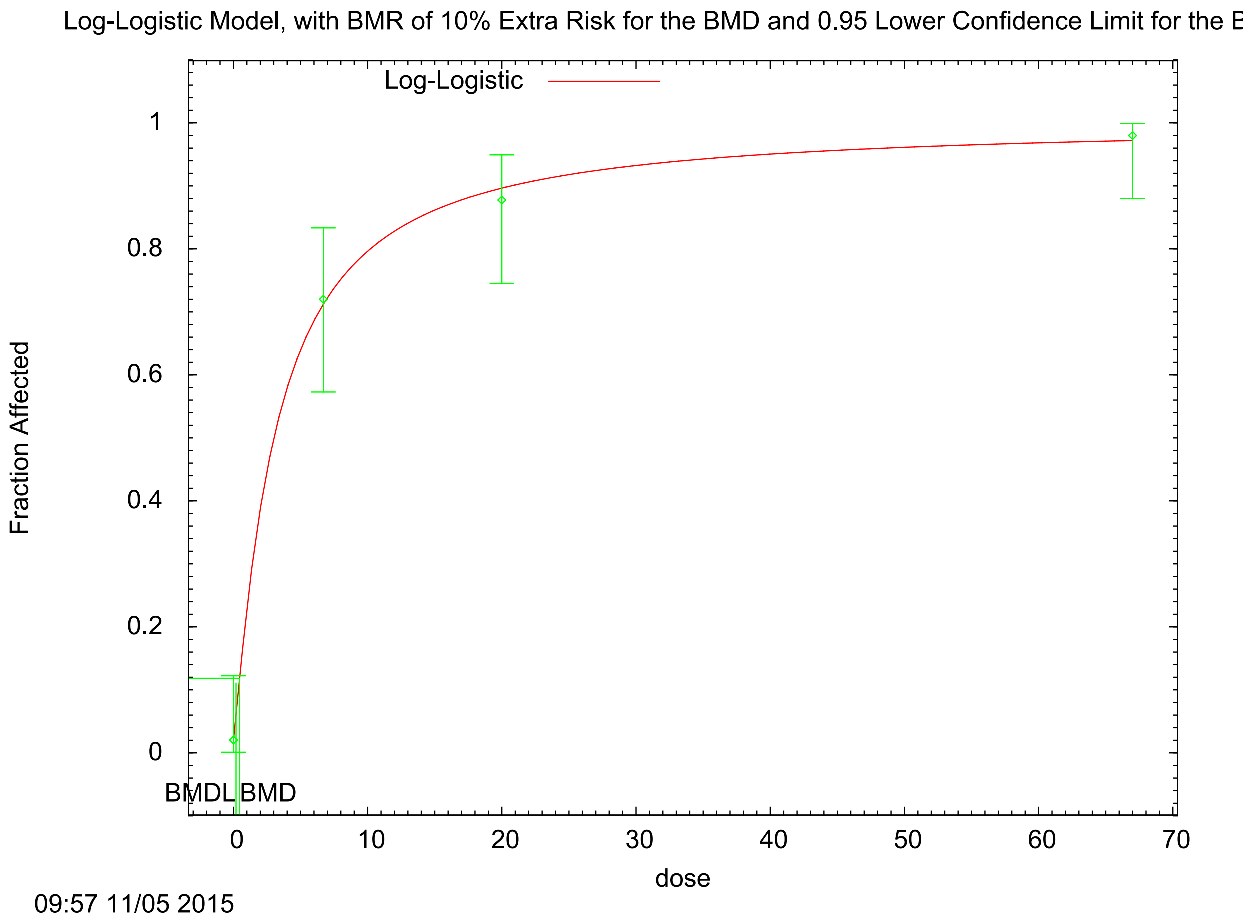


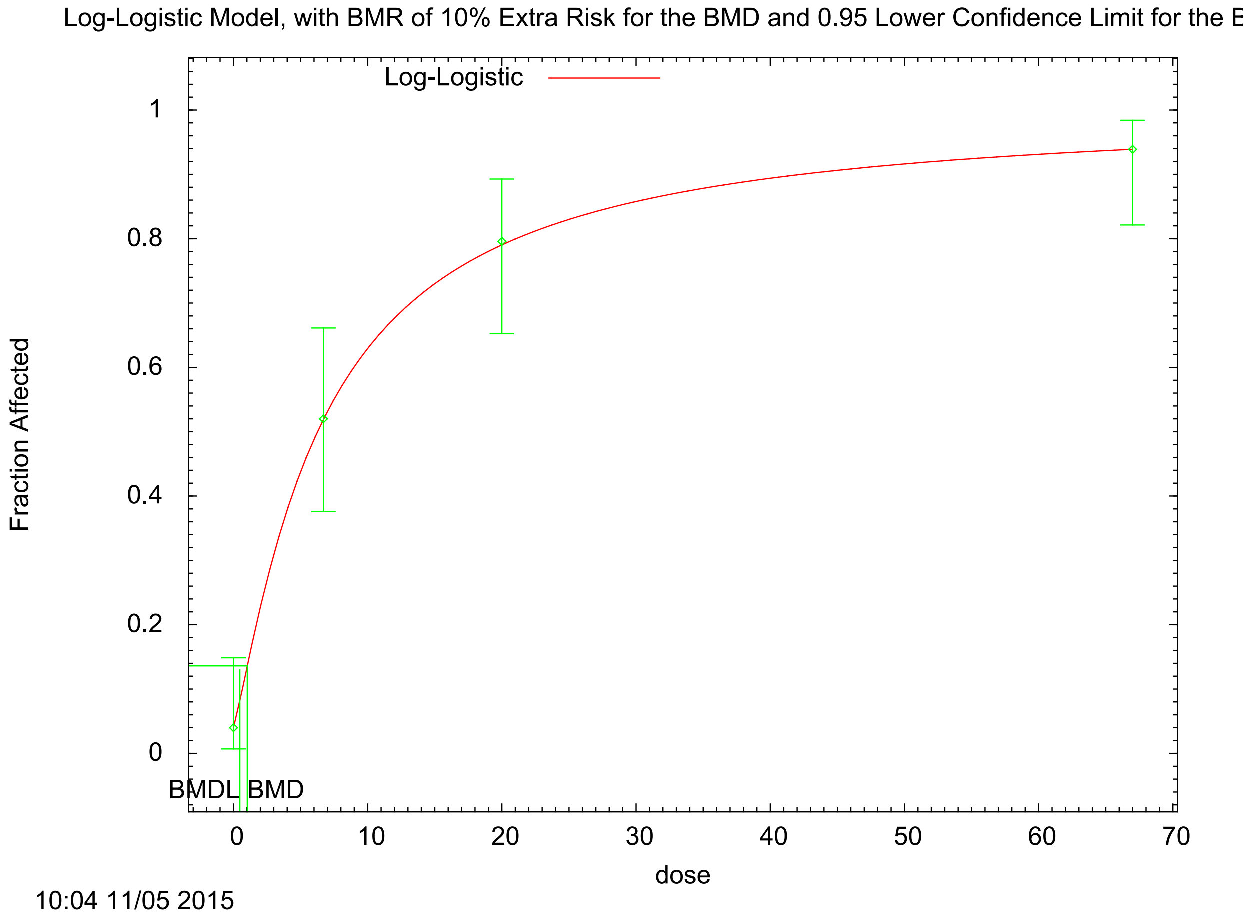
Table A-8. Model Predictions for Alveolar Epithelial Metaplasia in Female Mice Exposed to Molybdenum Trioxide (NTP 1997)

Model	DF	χ^2	χ^2 Goodness of fit p-value[a]	Scaled residuals[b] Dose below BMC	Dose above BMC	Overall largest	AIC	BMC_{10} (mg/m^3)	$BMCL_{10}$ (mg/m^3)
Gamma[c]	2	15.17	0.0005	-0.58	1.79	-3.32	171.71	ND	ND
Logistic	2	37.47	0.00	-3.49	2.02	-4.18	194.28	ND	ND
LogLogistic[d,e]	***1***	***0.00***	***0.94***	***0.00***	***-0.02***	***0.05***	***164.20***	***1.03***	***0.47***
LogProbit[d]	2	6.53	0.04	0.22	1.25	-2.20	166.91	ND	ND
Multistage (1-degree)[f]	2	15.17	0.0005	-0.58	1.79	-3.32	171.71	ND	ND
Multistage (2-degree)[f]	2	15.17	0.0005	-0.58	1.79	-3.32	171.71	ND	ND
Multistage (3-degree)[f]	2	15.17	0.0005	-0.58	1.79	-3.32	171.71	ND	ND
Probit	2	33.34	0.00	-3.87	1.94	-3.87	199.12	ND	ND
Weibull[c]	2	15.17	0.0005	-0.58	1.79	-3.32	171.71	ND	ND

[a]Values <0.1 fail to meet conventional goodness-of-fit criteria.
[b]Scaled residuals at doses immediately below and above the BMC; also the largest residual at any dose.
[c]Power restricted to ≥1.
[d]Slope restricted to ≥1.
[e]Selected model. The only model that provided adequate fit to the data was the Log-Logistic model.
[f]Betas restricted to ≥0.

AIC = Akaike Information Criterion; BMC = maximum likelihood estimate of the exposure concentration associated with the selected benchmark response; BMCL = 95% lower confidence limit on the BMC (subscripts denote benchmark response: i.e., $_{10}$ = exposure concentration associated with 10% extra risk); DF = degrees of freedom; ND = not determined, goodness-of-fit criteria, p<0.10

Figure A-7. Fit of LogLogistic Model to Data on Incidence of Alveolar Epithelial Metaplasia in Female Mice Exposed to Molybdenum Trioxide (mg/m^3)



Uncertainty Factors used in MRL derivation:

[ ] 10 for use of a LOAEL
[X] 3 for extrapolation from animals to humans with dosimetric adjustments
[X] 10 for human variability

Was a conversion factor used from ppm in food or water to a mg/body weight dose? Not applicable.

If an inhalation study in animals, list conversion factors used in determining human equivalent dose: HECs were calculated for each potential POD by adjusting for intermittent exposure (6 hours/24 hours, 5 days/7 days) and multiplying the POD_{ADJ} by the RDDR for the appropriate region of the respiratory tract. The RDDRs were calculated using EPA's RDDR calculator with reference body weights of 0.40, 0.25, 0.040, and 0.035 kg for the male rats, female rats, male mice, and female mice, respectively. The POD_{HEC} values are presented in Table A-9.

Table A-9. Summary of Potential Points of Departures (PODs) and Human Equivalent Concentrations (HECs)

End point	PODs (mg Mo/m^3)	RDDR values	HECs[a] (mg Mo/m^3)
Squamous metaplasia of the epiglottis in male rats	3.53 (BMCL)	0.459	0.28
Hyaline degeneration of the respiratory epithelium in female rats	4.26 (BMCL)	0.248	0.19
Hyaline degeneration of the olfactory epithelium in female rats	6.7 (LOAEL)	0.248	0.30
Squamous metaplasia of the epiglottis in female rats	1.60 (BMCL)	0.248	0.071
Squamous metaplasia of the epiglottis in male mice	0.47 (BMCL)	0.441	0.037
Histiocyte infiltration in the lungs of male mice	6.7 (LOAEL)	1.046	1.3
Alveolar epithelial metaplasia in male mice	0.35 (BMCL)	1.046	0.065
Squamous metaplasia of the epiglottis in female mice	0.19 (BMCL)	0.367	0.012
Alveolar epithelial metaplasia in female mice	0.47 (BMCL)	3.067	0.26

[a]HEC calculated by multiplying the duration-adjusted POD (POD x 6 hours/24 hours x 5 days/7days) by the RDDR value.

BMCL = 95% lower confidence limit on the benchmark concentration; HEC = human equivalent concentration; LOAEL = lowest observed adverse effect level; POD = point of departure; RDDR = regional deposited dose ratio for the specific region of the respiratory tract

Was a conversion used from intermittent to continuous exposure? As described above, the PODs were adjusted for intermittent exposure (6 hours/day, 5 days/week).

Other additional studies or pertinent information that lend support to this MRL: There are limited data on the toxicity of inhaled molybdenum in humans. A study of workers at a molybdenite roasting facility exposed to molybdenum trioxide and other oxides, found no alterations in lung function, but did find increases in serum uric acid levels (Walravens et al. 1979); the TWA molybdenum concentration was 9.46 mg molybdenum/m^3. Another study of workers exposed to ultrafine molybdenum trioxide dust reported respiratory symptoms (dyspnea and cough), radiographic abnormalities, and impaired lung function (Ott et al. 2004); the study did not provide monitoring data. Confidence in these cohort studies was considered very low (see Appendix B for additional information). Data on the chronic toxicity of molybdenum in laboratory animals is limited to 2-year studies in rats and mice exposed to molybdenum trioxide (NTP 1997).

Agency Contacts (Chemical Managers): Dan Todd

MINIMAL RISK LEVEL (MRL) WORKSHEET

Chemical Name: Molybdenum
CAS Numbers: 7439-98-7
Date: April 2017
Profile Status: Final for Public Comment
Route: [ ] Inhalation [X] Oral
Duration: [X] Acute [ ] Intermediate [ ] Chronic
Graph Key: 5
Species: Mouse

Minimal Risk Level: 0.05 [X] mg molybdenum/kg/day [ ] ppm

The MRL is calculated based on the assumption of healthy dietary levels of molybdenum and copper and represents the level of exposure above and beyond the normal diet.

Reference: Zhang Y-L, Liu F-J, Chen X-L, et al. 2013. Dual effects of molybdenum on mouse oocyte quality and ovarian oxidative stress. Sys Bio Repro Med 59:312-318.

Experimental design: Groups of 25 female ICR mice (4–8 weeks of age) were exposed to 0, 5, 10, 20, or 40 mg/L molybdenum as sodium molybdate dihydrate in distilled drinking water for 14 days. Doses of 0, 1.3, 2.6, 5.3, and 11 mg molybdenum/kg/day were estimated using a reference body weight of 0.0246 kg and water intake of 0.0065 L/day. The copper content of the commercial pellet diet was not reported, but it was assumed to be adequate. The following parameters were used to assess reproductive toxicity: ovarian weight, number of ovulations, oocyte ultrastructure, and oocyte quality.

Effect noted in study and corresponding doses: A significant decrease in relative ovarian weight was observed at 11 mg molybdenum/kg/day; no information on body weight gain was reported. Hyperemia was noted in the ovaries of mice exposed to 5.3 or 11 mg molybdenum/kg/day; however, the incidence and statistical significance was not reported. A significant increase in the rate of abnormal MII oocytes (defined as the [number of total ovulations – number of normal MII oocytes]/number of total ovulations) was observed at 11 mg molybdenum/kg/day. At 1.3 mg molybdenum/kg/day, there was a significant decrease in the number of abnormal oocytes and increase in the number of ovulations, which were considered beneficial effects. The oocyte abnormality rates are presented in Table A-10. The study also found some significant alterations in superoxide dismutase (increased at 2.6 mg molybdenum/kg/day and decreased at 5.3 and 11 mg molybdenum/kg/day), glutathione peroxidase (increased at 1.3 and 2.6 mg molybdenum/kg/day and decreased at 11 mg molybdenum/kg/day), and malondialdehyde (increased at 5.3 and 11 mg molybdenum/kg/day) levels.

Table A-10. MII Oocyte Morphology Alterations in Female Mice Exposed to Sodium Molybdate for 14 Days

Dose (mg Mo/kg/day)	MII oocyte abnormality rate (%)[a]
0	31.8542±2.3361
1.3	18.6753±0.8782[b]
2.6	28.4928±1.9862
5.3	34.4304±3.0439
11	45.4952±3.3147[b]

[a]Mean ± standard deviation; n = 25/group.
[b]Statistically different from controls, p<0.01.

Source: Zhang et al. 2013

Dose and end point used for MRL derivation: NOAEL of 5.3 and LOAEL of 11 mg molybdenum/kg/day for an increase in the rate of MII oocyte abnormalities.

[X] NOAEL [ ] LOAEL

BMD modeling was not used to identify a potential POD for the MRL. The plot of the rate of abnormal oocyte morphology versus dose has a U-shaped curve anchored by the beneficial effect observed at 1.3 mg molybdenum/kg/day and the adverse effect observed 11 mg molybdenum/kg/day. To accurately define the shape of the curve and allow for estimating a BMD for the adverse effect, additional data points would be needed. Thus, a NOAEL/LOAEL approach was used to identify the POD for the MRL.

Uncertainty Factors used in MRL derivation:

[ ] 10 for use of a LOAEL
[X] 10 for extrapolation from animals to humans
[X] 10 for human variability

Was a conversion factor used from ppm in food or water to a mg/body weight dose? Doses were estimated using the reported molybdenum concentration in the drinking water and reference drinking water intakes and body weight of 0.0065 L/day and 0.0246 kg, respectively.

If an inhalation study in animals, list conversion factors used in determining human equivalent dose: Not applicable.

Was a conversion used from intermittent to continuous exposure? Not applicable.

Other additional studies or pertinent information that lend support to this MRL: Two other studies evaluated the reproductive toxicity of molybdenum following acute-duration oral exposure. Significant decreases in sperm concentration and motility and increases in sperm abnormalities were observed in male mice exposed to 25 mg molybdenum/kg/day as sodium molybdate in drinking water for 14 days (Zhai et al. 2013). Bersenyi et al. (2008) reported reductions in mature spermatocytes in rabbits exposed to 0.58 mg molybdenum/kg/day as ammonium heptamolybdate in carrots; however, the incidence and statistical significance of the finding were not reported. Bersenyi et al. (2008) also examined female rabbits exposed to 1.2 mg molybdenum/kg/day as ammonium heptamolybdate in the diet and found no histological alterations in the ovaries. Male and female reproductive effects have also been observed in rats following intermediate-duration oral exposure (Fungwe et al. 1990; Lyubimov et al. 2004; Pandey and Singh 2002).

Limited data are available on the systemic toxicity of molybdenum following acute oral exposure. No alterations in uric acid levels were observed in volunteers administered 0.022 mg molybdenum/kg/day for 10 days (Deosthale and Gopalan 1974). No histological alterations were observed in the liver and kidneys of rabbits exposed to 1.2 mg molybdenum/kg/day in the diet for 14 days (Bersenyi et al. 2008); however, an increase in serum triglyceride levels was observed at this dose.

Agency Contacts (Chemical Managers): Dan Todd

MINIMAL RISK LEVEL (MRL) WORKSHEET

Chemical Name: Molybdenum
CAS Numbers: 7439-98-7
Date: April 2017
Profile Status: Final for Public Comment
Route: [ ] Inhalation [X] Oral
Duration: [ ] Acute [X] Intermediate [ ] Chronic
Graph Key: 24
Species: Rat

Minimal Risk Level: 0.008 [X] mg molybdenum/kg/day [ ] ppm

The MRL is calculated based on the assumption of healthy dietary levels of molybdenum and copper and represents the level of exposure above and beyond the normal diet.

Reference: Fungwe TV, Buddingh F, Demick DS, et al. 1990. The role of dietary molybdenum on estrous activity, fertility, reproduction and molybdenum and copper enzyme activities of female rats. Nutr Res 10:515-524.

Experimental design: Groups of 21 female Sprague-Dawley rats (21 days of age) were exposed to drinking water containing 0, 5, 10, 50, or 100 mg/L molybdenum as sodium molybdate dihydrate; doses of 0.76, 1.5, 7.6, and 15 mg molybdenum/kg/day were estimated using a reference water intake of 0.031 L/day and body weight of 0.204 kg (EPA 1988). The diet contained 0.025 mg/kg molybdenum and 6.3 mg/kg copper. The investigators noted that the average molybdenum intake from the diet was 0.002 mg/kg/day (0.00028 mg/kg/day). After 6 weeks of exposure, the estrous cycle was determined through three cycles by vaginal cytology and microscopic examination. At the end of the third cycle, groups of 15 rats were mated with unexposed males.

Effect noted in study and corresponding doses: No alterations in body weight gain were observed. Exposure to 1.5 mg/kg/day resulted a significant prolonging of the length of the estrus cycle. The investigators noted that the estrus phase appeared to be the most affected stage of estrous; it was extended by 6–12 hours in the affected animals. In the published paper, the estrous cycle length was presented in a histogram; using GrabIt! software, Figure 1 of the Fungwe et al. (1990) paper was digitized; the estrous cycle lengths are summarized in Table A-11. No significant alterations in the conception rate were observed. This study also reported several developmental effects in the rats exposed to ≥10 mg/L molybdenum; effects included decreased total litter weight and increased number of resorption sites. Because the copper content of the diet was lower than the recommended level of 8 ppm for gestational exposure, this portion of the study was not considered suitable for MRL derivation.

Table A-11. Estrous Cycle Length in Rats Exposed to Sodium Molybdate in the Drinking Water for 6 Weeks[a]

Dose (mg Mo/kg/day)	Estrous cycle length[b] (days)
0	4.48±0.29
0.76	4.49±0.27
1.5	5.06±0.26[c]
7.6	5.45±0.24[c]
15	5.43±0.31[c]

[a]Data extracted using GrabIt! Software from Figure 1 in the Fungwe et al. (1990) study.
[b]Mean ± standard error.
[c]Statistically different from controls, $p<0.05$.

Source: Fungwe et al. 1990

Dose and end point used for MRL derivation: The NOAEL and LOAEL values of 0.76 and 1.5 mg molybdenum/kg/day were used as the POD for the MRL.

[X] NOAEL [ ] LOAEL

BMD modeling of the estrous cycle length data in Table A-11 was conducted with EPA's BMDS (version 2.5.0). The following procedure for fitting continuous data was used. The simplest model (linear) was first applied to the data while assuming constant variance. If the data were consistent with the assumption of constant variance ($p\geq0.1$), then the fit of the linear model to the means was evaluated and the polynomial, power, exponential, and Hill models were fit to the data while assuming constant variance. Adequate model fit was judged by three criteria: goodness-of-fit p-value ($p>0.1$), visual inspection of the dose-response curve, and scaled residual at the data point (except the control) closest to the predefined BMR. If the test for constant variance was negative, the linear model was run again while applying the power model integrated into the BMDS to account for nonhomogenous variance. If the nonhomogenous variance model provided an adequate fit ($p\geq0.1$) to the variance data, then the fit of the linear model to the means was evaluated and the polynomial, power, exponential, and Hill models were fit to the data and evaluated while the variance model was applied. If the test for constant variance was negative and the nonhomogenous variance model did not provide an adequate fit to the variance data, then the data set was considered unsuitable for modeling. A BMR of 1 SD change from the control was selected. The data set for estrous cycle length was not adequate fit to the linear model under the assumption of constant variance or nonhomogenous variance. Thus, the NOAEL/LOAEL approach was used to identify the POD for the MRL.

Uncertainty Factors used in MRL derivation:

- [ ] 10 for use of a LOAEL
- [X] 10 for extrapolation from animals to humans
- [X] 10 for human variability

Was a conversion factor used from ppm in food or water to a mg/body weight dose? Doses were calculated using the reported drinking water concentrations and references water intake and body weights of 0.031 L/day and 0.204 kg.

If an inhalation study in animals, list conversion factors used in determining human equivalent dose: Not applicable.

Was a conversion used from intermittent to continuous exposure? Not applicable.

Other additional studies or pertinent information that lend support to this MRL: Several studies have reported reproductive effects following intermediate-duration; a summary of these studies is presented in Table A-12.

Table A-12. Reproductive Effects Observed in Rats Orally Exposed to Molybdenum

Duration (route)	NOAEL (mg Mo/kg/day)	LOAEL (mg Mo/kg/day)	Effect	Reference (compound)
8 weeks (drinking water)	0.76	1.5	Prolonged estrus phase; no effect on female fertility	Fungwe et al. 1990 (sodium molybdate)
≥8 weeks (diet)	7		No effect on fertility; male and female rats were exposed	Jeter and Davis 1954 (sodium molybdate)
59–61 days (males), 22–35 days (females) (gavage)	1.5	4.4	Decreases in sperm motility and sperm count, and increased sperm morphology. No effects in females	Lyubimov et al. 2004 (ammonium tetrathiomolybdate)
90 days (diet)	17	60	Decrease in percentage of progressive motile sperm. No significant alterations in other sperm parameters. No alterations in vaginal cytology, estrus cycle, or histology of male or female reproductive tissues	Murray et al. 2013 (sodium molybdate)
60 days (gavage)	3.4[a]	10[a]	Decreases in sperm count and motility; increases in sperm abnormalities	Pandey and Singh 2002 (sodium molybdate)
60 days (gavage)		10	Decreases in male fertility	Pandey and Singh 2002 (sodium molybdate)

[a]Adjusted for intermittent exposure (5 days/week).

Other effects that have been observed at higher doses include kidney damage at ≥60 mg molybdenum/kg/day (Bompart et al. 1990; Murray et al. 2013), neuromuscular effects at 54 mg molybdenum/kg/day (Arrington and Davis 1953), and body weight (most studies did not report alterations below 60 mg molybdenum/kg/day [Bompart et al. 1990; Mills et al. 1958; Murray et al. 2013; Van Reen and Williams 1956], although one study reported effects at 4.4 mg molybdenum/kg/day [Lyubimov et al. 2004]).

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APPENDIX B. FRAMEWORK FOR ATSDR'S SYSTEMATIC REVIEW OF HEALTH EFFECTS DATA FOR MOLYBDENUM

To increase the transparency of ATSDR's process of identifying, evaluating, synthesizing, and interpreting the scientific evidence on the health effects associated with exposure to molybdenum, ATSDR utilized a slight modification of NTP's Office of Health Assessment and Translation (OHAT) systematic review methodology (NTP 2013, 2015; Rooney et al. 2014). ATSDR's framework is an eight-step process for systematic review with the goal of identifying the potential health hazards of exposure to molybdenum:

- Step 1. Problem Formulation
- Step 2. Literature Search and Screen for Health Effects Studies
- Step 3. Extract Data from Health Effects Studies
- Step 4. Identify Potential Health Effect Outcomes of Concern
- Step 5. Assess the Risk of Bias for Individual Studies
- Step 6. Rate the Confidence in the Body of Evidence for Each Relevant Outcome
- Step 7. Translate Confidence Rating into Level of Evidence of Health Effects
- Step 8. Integrate Evidence to Develop Hazard Identification Conclusions

B.1 PROBLEM FORMULATION

The objective of the toxicological profile and this systematic review was to identify the potential health hazards associated with inhalation, oral, or dermal/ocular exposure to molybdenum. The inclusion criteria used to identify relevant studies examining the health effects of molybdenum are presented in Table B-1.

Data from human and laboratory animal studies were considered relevant for addressing this objective. Human studies were divided into two broad categories: observational epidemiology studies and controlled exposure studies. The observational epidemiology studies were further divided: cohort studies (retrospective and prospective studies), population studies (with individual data or aggregate data), and case-control studies.

B.2 LITERATURE SEARCH AND SCREEN FOR HEALTH EFFECTS STUDIES

A literature search and screen was conducted to identify studies examining the health effects of molybdenum. Studies for other sections of the toxicological profile were also identified in the literature search and screen step. Although these studies were not included in the systematic review process, the results of some studies (e.g., mechanistic studies, toxicokinetic studies) were considered in the final steps of the systematic review. ATSDR primarily focused on peer-reviewed articles without publication date or language restrictions. Non-peer-reviewed studies that were considered relevant to the assessment of the health effects of molybdenum have undergone peer review by at least three ATSDR-selected experts who have been screened for conflict of interest.

Table B-1. Inclusion Criteria for the Literature Search and Screen

Species
Human
Laboratory mammals
Route of exposure
Inhalation
Oral
Dermal (or ocular)
Parenteral (these studies will be considered supporting data)
Health outcome
Death
Systemic effects
Respiratory effects
Cardiovascular effects
Gastrointestinal effects
Hematological effects
Musculoskeletal effects
Hepatic effects
Renal effects
Endocrine effects
Dermal effects
Ocular effects
Body weight effects
Metabolic effects
Other systemic effects
Immunological effects
Neurological effects
Reproductive effects
Developmental effects
Cancer

B.2.1 Literature Search

The following databases were searched, without date restrictions, in December 2014:

- PubMed
- National Library of Medicine's TOXLINE
- Scientist and Technical Information Network's TOXCENTER
- National Pesticide Information Retrieval System (NPIRS)
- Toxic Substances Control Act Test Submissions (TSCATS) and TSCATS2

Review articles were identified and used for the purpose of providing background information and identifying additional references. ATSDR also identified reports from the grey literature, which included unpublished research reports, technical reports from government agencies, conference proceedings and abstracts, and theses and dissertations.

The search strategy used the chemical name, CAS numbers (i.e., 7439-98-7; 1317-33-5; 12033-29-3; 12033-33-9; 11098-99-0; 18868-43-4; 1313-27-5; 1313-29-7; 11098-84-3; 27546-07-2; 12054-85-2; 15060-55-6; 7631-95-0; 10102-40-6; 7789-82-4; 12011-97-1; 11119-46-3; 11062-51-4; 10241-05-1; 1309-56-4; 7783-77-9; 13939-06-5; 14221-06-8; 13814-74-9), synonyms, and Medical Subject Headings (MeSH) terms for molybdenum. A total of 9,217 records were identified and imported into EndNote (version 5). After the identification and removal of 489 duplicates by EndNote, the remaining 8,728 records were moved to the literature screening step.

B.2.2 Literature Screening

A two-step process was used to screen the literature search to identify relevant studies examining the health effects of molybdenum:

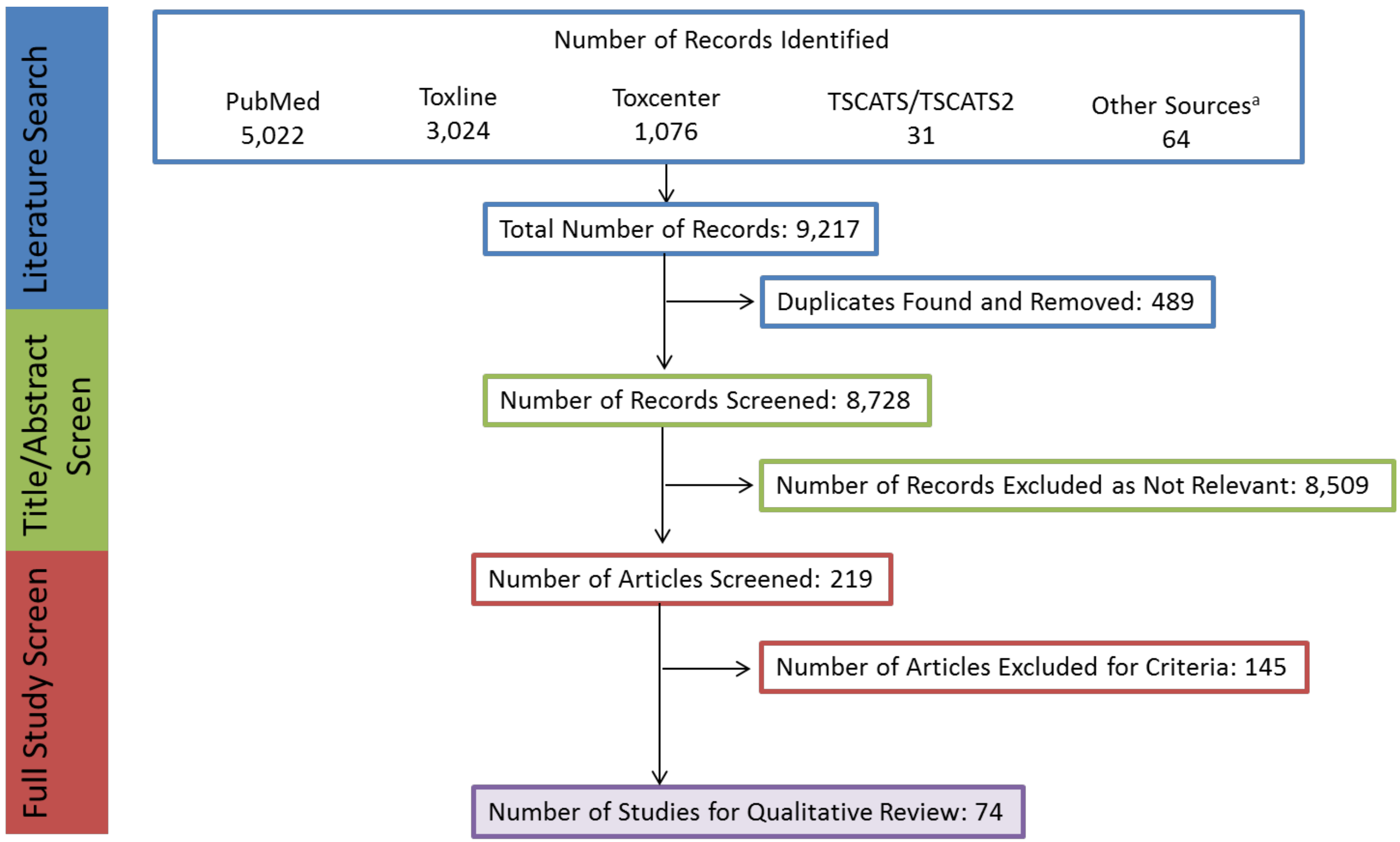
- Title and Abstract Screen
- Full Text Screen

Title and Abstract Screen. Within the Endnote library, titles and abstracts were screened manually for relevance. Studies that were considered relevant were moved to the second step of the literature screening process. Studies were excluded when the title and abstract clearly indicated that the study did not meet the inclusion criteria (Table B-1). In the Title and Abstract Screen step, 8,728 records were reviewed; 219 studies were considered relevant to Section 3.2 of the toxicological profile and were moved to the next step in the process.

Full Text Screen. The second step in the literature screening process was a full text review of individual studies considered relevant in the Title and Abstract Screen step. Each study was reviewed to determine whether it met the inclusion criteria; however, the quality of the studies was not evaluated at this step of the process. Of the 219 studies undergoing Full Text Screen, 145 studies did not meet the inclusion criteria; some of the excluded studies were used as background information on toxicokinetics or mechanisms of action or were relevant to other sections of the toxicological profile.

A summary of the results of the literature search and screening is presented in Figure B-1.

Figure B-1. Literature Search and Screen for Molybdenum Health Effect Studies



[a]Red numbers will go up based on new records found during reference check (excluded not relevant will be new items cited but not in Section 3.2, articles screened will go up based on new references cited in Section 3.2).

B.3 EXTRACT DATA FROM HEALTH EFFECTS STUDIES

Relevant data extracted from the individual studies selected for inclusion in the systematic review were collected in customized data forms in Distiller. A summary of the type of data extracted from each study is presented in Table B-2. For references that included more than one experiment or species, data extraction records were created for each experiment or species.

A summary of the extracted data for each study is presented in the Supplemental Document for Molybdenum and overviews of the results of the inhalation, and oral exposure studies are presented in Section 3.2 of the profile and in the Levels Significant Exposures tables in Section 3.2 of the profile (Tables 3-1 and 3-2, respectively).

B.4 IDENTIFY POTENTIAL HEALTH EFFECT OUTCOMES OF CONCERN

Overviews of the potential health effect outcomes for molybdenum identified in human and animal studies are presented in Tables B-3 and B-4, respectively. The available human studies examined a limited number of end points and reported respiratory, hepatic, endocrine, other systemic (alterations in uric acid levels), reproductive, and developmental effects. Animal studies examined a number of end points following inhalation and oral exposure; no dermal exposure studies were identified. These studies examined most systemic end points and reported respiratory, gastrointestinal, hematological, musculoskeletal, hepatic, renal, endocrine, dermal, and body weight effects. Additionally, animal studies have reported neurological, reproductive, and developmental effects. Although animal studies have identified a number of affected tissues and systems, interpretation of much of the data is limited by an inadequate amount of copper in the diet. Studies in which the diet did not contain adequate levels of copper were carried through Step 3 of the systematic review, but were not considered in the identification of potential health effect outcomes of concern. Additionally, body weight effects were not considered a primary effect especially since most studies did not provide data on food intake; thus, this end point was not considered in the assessment of potential human hazards.

Table B-2. Data Extracted From Individual Studies

- Citation
- Chemical form
- Route of exposure (e.g., inhalation, oral, dermal)
    - Specific route (e.g., gavage in oil, drinking water)
- Species
    - Strain
- Exposure duration category (e.g., acute, intermediate, chronic)
- Exposure duration
    - Frequency of exposure (e.g., 6 hours/day, 5 days/week)
    - Exposure length
- Number of animals or subjects per sex per group
- Dose/exposure levels
- Parameters monitored
- Description of the study design and method
- Summary of calculations used to estimate doses (if applicable)
- Summary of the study results
- Reviewer's comments on the study
- Outcome summary (one entry for each examined outcome)
    - No-observed-adverse-effect level (NOAEL) value
    - Lowest-observed-adverse-effect level (LOAEL) value
    - Effect observed at the LOAEL value

Table B-3. Overview of the Health Outcomes for Molybdenum Evaluated In Human Studies

	Systemic effects: Respiratory	Cardiovascular	Gastrointestinal	Hematological	Musculoskeletal	Hepatic	Renal	Endocrine	Dermal	Ocular	Body weight	Metabolic	Other	Immunological effects	Neurological effects	Reproductive effects	Developmental effects	Cancer
Inhalation studies																		
Cohort	2 1												1 1					1 1
Case control																		
Population																		
Controlled exposure																		
Oral studies																		
Cohort												1 1	1 1			2 2	2 1	
Case control																		
Population						1 1		3 3										
Controlled exposure													1 0					
Dermal studies																		
Cohort																		
Case control																		
Population																		
Controlled Exposure																		

Number of studies examining end point: 0 | 1 | 2 | 3 | 4 | 5-9 | ≥10

Number of studies reporting outcome 0 | 1 | 2 | 3 | 4 | 5-9 | ≥10

Table B-4. Overview of the Health Outcomes for Molybdenum Evaluated in Experimental Animal Studies

	Systemic effects: Respiratory	Systemic effects: Cardiovascular	Systemic effects: Gastrointestinal	Systemic effects: Hematological	Systemic effects: Musculoskeletal	Systemic effects: Hepatic	Systemic effects: Renal	Systemic effects: Endocrine	Systemic effects: Dermal	Systemic effects: Ocular	Systemic effects: Body weight	Systemic effects: Metabolic	Systemic effects: Other	Immunological effects	Neurological effects	Reproductive effects	Developmental effects	Cancer
Inhalation studies																		
Acute-duration	2 0																	
Intermediate-duration	2 0																	
Chronic-duration	2 2																	2 2
Oral studies																		
Acute-duration					4 4	2 1	2 1				5 0					4 3		
Intermediate-duration	1 0	2 0	3 1	16 5	9 8	8 7	8 8	6 5	2 2	0 0	31 24	2 0	1 0		2 1	10 7	8 4	
Chronic-duration																		
Dermal studies																		
Acute-duration																		
Intermediate-duration																		
Chronic-duration																		

Number of studies examining end point 0 | 1 | 2 | 3 | 4 | 5-9 | ≥10

Number of studies reporting outcome 0 | 1 | 2 | 3 | 4 | 5-9 | ≥10

B.5 ASSESS THE RISK OF BIAS FOR INDIVIDUAL STUDIES

B.5.1 Risk of Bias Assessment

The risk of bias of individual studies was assessed using OHAT's Risk of Bias Tool (NTP 2015). The risk of bias questions for observational epidemiology studies, human-controlled exposure studies, and animal experimental studies are presented in Tables B-5, B-6, and B-7, respectively. Each risk of bias question was answered on a four-point scale:

- **Definitely low risk of bias (++)**
- **Probably low risk of bias (+)**
- **Probably high risk of bias (-)**
- **Definitely high risk of bias (– –)**

In general, "definitely low risk of bias" or "definitely high risk of bias" were used if the question could be answered with information explicitly stated in the study report. If the response to the question could be inferred, then "probably low risk of bias" or "probably high risk of bias" responses were typically used.

Table B-5. Risk of Bias Questionnaire for Observational Epidemiology Studies

Selection bias
Were the comparison groups appropriate?
Confounding bias
Did the study design or analysis account for important confounding and modifying variables?
Attrition/exclusion bias
Were outcome data complete without attrition or exclusion from analysis?
Detection bias
Is there confidence in the exposure characterization?
Is there confidence in outcome assessment?
Selective reporting bias
Were all measured outcomes reported?

Table B-6. Risk of Bias Questionnaire for Human-Controlled Exposure Studies

Selection bias
Was administered dose or exposure level adequately randomized?
Was the allocation to study groups adequately concealed?
Performance bias
Were the research personnel and human subjects blinded to the study group during the study?
Attrition/exclusion bias
Were outcome data complete without attrition or exclusion from analysis?
Detection bias
Is there confidence in the exposure characterization?
Is there confidence in outcome assessment?
Selective reporting bias
Were all measured outcomes reported?

Table B-7. Risk of Bias Questionnaire for Experimental Animal Studies

Selection bias
Was administered dose or exposure level adequately randomized?
Was the allocation to study groups adequately concealed?
Performance bias
Were experimental conditions identical across study groups?
Were the research personnel blinded to the study group during the study?
Attrition/exclusion bias
Were outcome data complete without attrition or exclusion from analysis?
Detection bias
Is there confidence in the exposure characterization?
Is there confidence in outcome assessment?
Selective reporting bias
Were all measured outcomes reported?
Other bias
Did the study design or analysis account for important confounding and modifying variables? This question addresses whether the copper levels of the diet met nutritional requirements.

After the risk of bias questionnaires were completed for the health effects studies, the studies were assigned to one of three risk of bias tiers based on the responses to the key questions listed below and the responses to the remaining questions.

- Is there confidence in the exposure characterization? (only relevant for observational studies)
- Is there confidence in the outcome assessment?
- Does the study design or analysis account for important confounding and modifying variables? (only relevant for observational studies)

First Tier. Studies placed in the first tier received ratings of "definitely low" or "probably low" risk of bias on the key questions **AND** received a rating of "definitely low" or "probably low" risk of bias on the responses to at least 50% of the other applicable questions.

Second Tier. A study was placed in the second tier if it did not meet the criteria for the first or third tiers.

Third Tier. Studies placed in the third tier received ratings of “definitely high” or “probably high” risk of bias for the key questions **AND** received a rating of “definitely high” or “probably high” risk of bias on the response to at least 50% of the other applicable questions.

The results of the risk of bias assessment for the different types of molybdenum health effects studies (observational epidemiology, human experimental, and animal experimental studies) are presented in Tables B-8, B-9, and B-10, respectively.

Table B-8. Summary of Risk of Bias Assessment for Molybdenum—Observational Epidemiology Studies

	Risk of bias criteria and ratings						
	Selection bias	Confounding bias	Attrition / exclusion bias	Detection bias		Selective reporting bias	
Reference	Were the comparison groups appropriate?	Did the study design or analysis account for important confounding and modifying variables?*	Were outcome data complete without attrition or exclusion from analysis?	Is there confidence in the exposure characterization?*	Is there confidence in the outcome assessment?*	Were all measured outcomes reported?	Risk of bias tier
Outcome: Respiratory effects							
Cohort studies							
Ott et al. 2004	–	–	+	na	+	++	Second
Walravens et al. 1979	–	–	+	+	–	+	Second
Outcome: Hepatic effects							
Cross-sectional studies							
Mendy et al. 2012	+	+	+	+	–	+	Second
Outcome: Alterations in Uric Acid Levels							
Cross-sectional studies							
Koval'sky et al. 1961	–	–	+	–	+	+	Second
Cohort studies							
Walravens et al. 1979	–	–	+	+	–	+	Second
Outcome: Reproductive Effects							
Cross-sectional studies							
Lewis and Meeker 2015	na	-	+	+	+	+	First
Meeker et al. 2008	+	+	+	++	++	++	First
Meeker et al. 2010	+	+	++	+	++	++	First

Table B-8. Summary of Risk of Bias Assessment for Molybdenum—Observational Epidemiology Studies

	Risk of bias criteria and ratings						
	Selection bias	Confounding bias	Attrition / exclusion bias	Detection bias		Selective reporting bias	
Reference	Were the comparison groups appropriate?	Did the study design or analysis account for important confounding and modifying variables?*	Were outcome data complete without attrition or exclusion from analysis?	Is there confidence in the exposure characterization?*	Is there confidence in the outcome assessment?*	Were all measured outcomes reported?	Risk of bias tier
Outcome: Developmental Effects							
Cross-sectional studies							
Vazquez-Salas et al. 2014	+	+	+	+	++	+	First
Shirai et al. 2010	na	–	+	+	+	+	Second

++ = definitely low risk of bias; + = probably low risk of bias; – = probably high risk of bias; – – = definitely high risk of bias; na = not applicable

*Key question used to assign risk of bias tier.

Table B-9. Summary of Risk of Bias Assessment for Molybdenum—Human-Controlled Exposure Studies

	Risk of bias criteria and ratings							
	Selection bias		Performance bias	Attrition/ exclusion bias	Detection bias		Selective reporting bias	
Reference	Was administered dose or exposure level adequately randomized?	Was the allocation to study groups adequately concealed?	Were the research personnel blinded to the study group during the study?	Were outcome data complete without attrition or exclusion from analysis?	Is there confidence in the exposure characterization?	Is there confidence in the outcome assessment?*	Were all measured outcomes reported?	Risk of bias tier
Outcome: Alterations in Uric Acid Levels								
Oral acute exposure								
Deosthale and Gopalan 1974	na	+	+	+	+	+	++	First

++ = definitely low risk of bias; + = probably low risk of bias; – = probably high risk of bias; – – = definitely high risk of bias; na = not applicable

*Key question used to assign risk of bias tier.

Table B-10. Summary of Risk of Bias Assessment for Molybdenum—Experimental Animal Studies

	Risk of bias criteria and ratings									
	Selection bias		Performance bias		Attrition/ exclusion bias	Detection bias		Selective reporting bias	Other bias	
Reference	Was administered dose or exposure level adequately randomized?	Was the allocation to study groups adequately concealed?	Were experimental conditions identical across study groups?	Were the research personnel blinded to the study group during the study?	Were outcome data complete without attrition or exclusion from analysis?	Is there confidence in the exposure characterization?	Is there confidence in the outcome assessment?*	Were all measured outcomes reported?	Did the study design or analysis account for important confounding and modifying variables?	Risk of bias tier
Outcome: Respiratory effects										
Inhalation acute exposure										
NTP 1997 (rat)	++	+	++	+	++	++	++	++	+	First
NTP 1997 (mouse)	++	+	++	+	++	++	++	++	+	First
Inhalation intermediate exposure										
NTP 1997 (rat)	++	+	++	+	++	++	++	++	+	First
NTP 1997 (mouse)	++	+	++	+	++	++	++	++	+	First
Inhalation chronic exposure										
NTP 1997 (rat)	++	+	++	+	++	++	++	++	+	First
NTP 1997 (mouse)	++	+	++	+	++	++	++	++	+	First
Outcome: Hepatic effects										
Inhalation intermediate exposure										
NTP 1997 (rat)	++	+	++	+	++	++	++	++	+	First
NTP 1997 (mouse)	++	+	++	+	++	++	++	++	+	First

Table B-10. Summary of Risk of Bias Assessment for Molybdenum—Experimental Animal Studies

	Risk of bias criteria and ratings									
	Selection bias		Performance bias		Attrition/ exclusion bias	Detection bias		Selective reporting bias	Other bias	
Reference	Was administered dose or exposure level adequately randomized?	Was the allocation to study groups adequately concealed?	Were experimental conditions identical across study groups?	Were the research personnel blinded to the study group during the study?	Were outcome data complete without attrition or exclusion from analysis?	Is there confidence in the exposure characterization?	Is there confidence in the outcome assessment?*	Were all measured outcomes reported?	Did the study design or analysis account for important confounding and modifying variables?	Risk of bias tier
Inhalation chronic exposure										
NTP 1997 (rat)	++	+	++	+	++	++	++	++	+	First
NTP 1997 (mouse)	++	+	++	+	++	++	++	++	+	First
Oral acute exposure										
Bersenyi et al. 2008 (rabbit)	−	+	+	−	++	−	+	+	+	First
Bersenyi et al. 2008 (rabbit)	−	+	+	−	++	−	+	+	+	First
Oral intermediate exposure										
Murray et al. 2013 (rat)	++	+	++	−	++	++	++	++	++	First
Rana and Chauhan 2000 (rat)	−	+	+	−	++	+	−	++	−	Second
Rana and Kumar 1980b (rat)	−	+	+	−	++	−	−	+	−	Third
Rana and Kumar 1980c (rat)	+	+	−	−	++	−	+	++	−	First
Rana and Kumar 1983 (rat)	+	+	−	−	++	+	+	++	−	First
Rana and Prakash 1986 (rat)	−	+	+	−	++	−	+	+	+	First

Table B-10. Summary of Risk of Bias Assessment for Molybdenum—Experimental Animal Studies

	Risk of bias criteria and ratings									
	Selection bias		Performance bias		Attrition/ exclusion bias	Detection bias		Selective reporting bias	Other bias	
Reference	Was administered dose or exposure level adequately randomized?	Was the allocation to study groups adequately concealed?	Were experimental conditions identical across study groups?	Were the research personnel blinded to the study group during the study?	Were outcome data complete without attrition or exclusion from analysis?	Is there confidence in the exposure characterization?	Is there confidence in the outcome assessment?*	Were all measured outcomes reported?	Did the study design or analysis account for important confounding and modifying variables?	Risk of bias tier
Rana et al. 1980 (rat)	−	+	+	−	+	−	+	+	+	First
Rana et al. 1985 (rat)	+	+	+	−	++	+	+	+	+	First
Outcome: Renal effects										
Inhalation intermediate exposure										
NTP 1997 (rat)	++	+	++	+	++	++	++	++	+	First
NTP 1997 (mouse)	++	+	++	+	++	++	++	++	+	First
Inhalation chronic exposure										
NTP 1997 (rat)	++	+	++	+	++	++	++	++	+	First
NTP 1997 (mouse)	++	+	++	+	++	++	++	++	+	First
Oral acute exposure										
Bersenyi et al. 2008 (rabbit, males)	−	+	+	−	++	−	+	+	+	First
Bersenyi et al. 2008 (rabbit, females)	−	+	+	−	++	−	+	+	+	First

Table B-10. Summary of Risk of Bias Assessment for Molybdenum—Experimental Animal Studies

	Risk of bias criteria and ratings									
	Selection bias		Performance bias		Attrition/ exclusion bias	Detection bias		Selective reporting bias	Other bias	
Reference	Was administered dose or exposure level adequately randomized?	Was the allocation to study groups adequately concealed?	Were experimental conditions identical across study groups?	Were the research personnel blinded to the study group during the study?	Were outcome data complete without attrition or exclusion from analysis?	Is there confidence in the exposure characterization?	Is there confidence in the outcome assessment?*	Were all measured outcomes reported?	Did the study design or analysis account for important confounding and modifying variables?	Risk of bias tier
Oral intermediate exposure										
Bandyopadhyay et al. 1981 (rat)	–	+	+	–	++	–	+	++	++	First
Bompart et al. 1990 (rat)	+	+	+	–	++	+	+	++	+	First
Murray et al. 2013 (rat)	++	+	++	–	++	++	++	++	++	First
Rana et al. 1980 (rat)	–	+	+	–	+	–	+	+	+	First
Rana and Kumar 1980c	+	+	–	–	++	–	+	++	–	First
Rana and Kumar 1983 (rat)	+	+	–	–	++	+	+	++	–	First
Outcome: Alterations in Uric Acid Levels										
Oral intermediate exposure										
Murray et al. 2013 (rat)	++	+	++	-	++	++	++	++	++	First
Outcome: Reproductive effects										
Inhalation intermediate exposure										
NTP 1997 (rat)	++	+	++	+	++	++	++	++	+	First
NTP 1997 (mouse)	++	+	++	+	++	++	++	++	+	First

Table B-10. Summary of Risk of Bias Assessment for Molybdenum—Experimental Animal Studies

	Risk of bias criteria and ratings									
	Selection bias		Performance bias		Attrition/ exclusion bias	Detection bias		Selective reporting bias	Other bias	
Reference	Was administered dose or exposure level adequately randomized?	Was the allocation to study groups adequately concealed?	Were experimental conditions identical across study groups?	Were the research personnel blinded to the study group during the study?	Were outcome data complete without attrition or exclusion from analysis?	Is there confidence in the exposure characterization?	Is there confidence in the outcome assessment?*	Were all measured outcomes reported?	Did the study design or analysis account for important confounding and modifying variables?	Risk of bias tier
Oral acute exposure										
Zhang et al. 2013 (mouse)	–	+	++	–	++	– –	+	++	–	First
Zhai et al. 2013 (mouse)	–	+	++	–	++	– –	+	++	+	First
Bersenyi et al. 2008 (rabbit, males)	–	+	+	–	++	–	+	+	+	First
Bersenyi et al. 2008 (rabbit, females)	–	+	+	–	++	–	+	+	+	First
Oral intermediate exposure										
Fungwe et al. 1990 (rat)	+	+	+	–	++	–	+	+	– –	First
Jeter and Davis 1954 (rat, adults)	–	+	+	–	++	–	+	+	–	First
Jeter and Davis 1954 (rat, weanling)	–	+	+	–	++	–	+	+	– –	First
Lyubimov et al. 2004 (rat)	+	+	++	–	++	+	+	++	++	First
Murray et al. 2013 (rat)	++	+	++	–	++	++	++	++	++	First
Pandey and Singh 2002 (rat)	–	+	++	–	++	+	+	++	–	First

Table B-10. Summary of Risk of Bias Assessment for Molybdenum—Experimental Animal Studies

	Risk of bias criteria and ratings									
	Selection bias		Performance bias		Attrition/ exclusion bias	Detection bias		Selective reporting bias	Other bias	
Reference	Was administered dose or exposure level adequately randomized?	Was the allocation to study groups adequately concealed?	Were experimental conditions identical across study groups?	Were the research personnel blinded to the study group during the study?	Were outcome data complete without attrition or exclusion from analysis?	Is there confidence in the exposure characterization?	Is there confidence in the outcome assessment?*	Were all measured outcomes reported?	Did the study design or analysis account for important confounding and modifying variables?	Risk of bias tier
Pandey and Singh 2002 (rat fertility study)	–	+	++	–	++	+	+	++	–	First
Outcome: Developmental effects										
Oral intermediate exposure										
Jeter and Davis 1954 (rat, weanling)	–	+	+	–	++	–	+	+	– –	First
Lyubimov et al. 2004 (rat)	+	+	++	–	++	+	+	++	++	First
Murray et al. 2014 (rat)	++	+	+	–	++	++	+	++	+	First
Pandey and Singh 2002 (rat)	–	+	++	–	++	+	+	++	–	First

++ = definitely low risk of bias; + = probably low risk of bias; – = probably high risk of bias; – – = definitely high risk of bias; na = not applicable

*Key question used to assign risk of bias tier.

B.6 RATE THE CONFIDENCE IN THE BODY OF EVIDENCE FOR EACH RELEVANT OUTCOME

Confidences in the bodies of human and animal evidence were evaluated independently for each potential outcome. ATSDR did not evaluate the confidence in the body of evidence for carcinogenicity; rather, the Agency defaulted to the cancer weight-of-evidence assessment of other agencies including DHHS, EPA, and IARC. The confidence in the body of evidence for an association or no association between exposure to molybdenum and a particular outcome was based on the strengths and weaknesses of individual studies. Four descriptors were used to describe the confidence in the body of evidence for effects or when no effect was found:

- **High confidence:** the true effect is highly likely to be reflected in the apparent relationship
- **Moderate confidence:** the true effect may be reflected in the apparent relationship
- **Low confidence:** the true effect may be different from the apparent relationship
- **Very low confidence:** the true effect is highly likely to be different from the apparent relationship

Confidence in the body of evidence for a particular outcome was rated for each type of study: case-control, case series, cohort, population, human-controlled exposure, and experimental animal. In the absence of data to the contrary, data for a particular outcome were collapsed across animal species, routes of exposure, and exposure durations. If species (or strain), route, or exposure duration differences were noted, then the data were treated as separate outcomes.

B.6.1 Initial Confidence Rating

In ATSDR's modification to the OHAT approach, the body of evidence for an association (or no association) between exposure to molybendum and a particular outcome was given an initial confidence rating based on the key features of the individual studies examining that outcome. The presence of these key features of study design was determined for individual studies using four "yes or no" questions in Distiller, which were customized for epidemiology or experimental animal study designs. Separate questionnaires were completed for each outcome assessed in a study. The key features for observational epidemiology (cohort, population, and case-control) studies, human-controlled exposure studies, and experimental animal studies are presented in Tables B-11, B-12, and B-13, respectively. The initial confidence in the study was determined based on the number of key features present in the study design:

- **High Initial Confidence:** Studies in which the responses to the four questions were "yes".

- **Moderate Initial Confidence:** Studies in which the responses to only three of the questions were "yes".

- **Low Initial Confidence:** Studies in which the responses to only two of the questions were "yes".

- **Very Low Initial Confidence:** Studies in which the response to one or none of the questions was "yes".

Table B-11. Key Features of Study Design for Observational Epidemiology Studies

Exposure was experimentally controlled
Exposure occurred prior to the outcome
Outcome was assessed on individual level rather than at the population level
A comparison group was used

Table B-12. Key Features of Study Design for Human-Controlled Exposure Studies

A comparison group was used or the subjects served as their own control
A sufficient number of subjects were tested
Appropriate methods were used to measure outcomes (i.e., clinically-confirmed outcome versus self-reported)
Appropriate statistical analyses were performed and reported or the data were reported in such a way to allow independent statistical analysis

Table B-13. Key Features of Study Design for Experimental Animal Studies

A concurrent control group was used
A sufficient number of animals per group were tested
Appropriate parameters were used to assess a potential adverse effect
Appropriate statistical analyses were performed and reported or the data were reported in such a way to allow independent statistical analysis

The presence or absence of the key features and the initial confidence levels for studies examining respiratory, gastrointestinal, renal, dermal, and ocular effects observed in the observational epidemiology, human experimental, and animal experimental studies are presented in Tables B-14, B-15, and B-16, respectively.

A summary of the initial confidence ratings for each outcome is presented in Table B-17. If individual studies for a particular outcome and study type had different study quality ratings, then the highest confidence rating for the group of studies was used to determine the initial confidence rating for the body of evidence; any exceptions were noted in Table B-17.

Table B-14. Presence of Key Features of Study Design for Molybdenum—Observational Epidemiology Studies

Reference	Key features: Controlled exposure	Key features: Exposure prior to outcome	Key features: Outcomes assessed on an individual level	Key features: Comparison group	Initial study confidence
Outcome: Respiratory effects					
Cohort studies					
Ott et al. 2004	No	Yes	Yes	No	Low
Walravens et al. 1979	No	No	No	No	Very Low
Outcome: Hepatic effects					
Cross-sectional studies					
Mendy et al. 2012	No	No	Yes	Yes	Low
Outcome: Alterations in Uric Acid Levels					
Cross-sectional studies					
Koval'sky et al. 1961	No	Yes	Yes	No	Low
Cohort studies					
Walravens et al. 1979	No	No	No	No	Very Low
Outcome: Reproductive Effects					
Cross-sectional studies					
Lewis and Meeker 2015	No	No	Yes	Yes	Low
Meeker et al. 2008	No	No	Yes	Yes	Low
Meeker et al. 2010	No	No	Yes	Yes	Low
Outcome: Developmental Effects					
Cross-sectional studies					
Vazquez-Salas et al. 2014	No	No	Yes	Yes	Low
Shirai et al. 2010	No	No	Yes	Yes	Low

Table B-15. Presence of Key Features of Study Design for Molybdenum—Human-Controlled Exposure Studies

	Key feature				
Reference	Concurrent control group or self-control	Sufficient number of subjects tested	Appropriate methods to measure outcome	Adequate data for statistical analysis	Initial study confidence
Outcome: Alterations in Uric Acid Levels					
Oral acute exposure					
Deosthale and Gopalan 1974	Yes	No	Yes	No	Low

Table B-16. Presence of Key Features of Study Design for Molybdenum—Experimental Animal Studies

Reference	Key feature: Concurrent control group	Key feature: Sufficient number of animals per group	Key feature: Appropriate parameters to assess potential effect	Key feature: Adequate data for statistical analysis	Initial study confidence
Outcome: Respiratory effects					
Inhalation acute exposure					
NTP 1997 (rat)	Yes	Yes	Yes	Yes	High
NTP 1997 (mouse)	Yes	Yes	Yes	Yes	High
Inhalation intermediate exposure					
NTP 1997 (rat)	Yes	Yes	Yes	Yes	High
NTP 1997 (mouse)	Yes	Yes	Yes	Yes	High
Inhalation chronic exposure					
NTP 1997 (rat)	Yes	Yes	Yes	Yes	High
NTP 1997 (mouse)	Yes	Yes	Yes	Yes	High
Outcome: Hepatic effects					
Inhalation intermediate exposure					
NTP 1997 (rat)	Yes	Yes	Yes	Yes	High
NTP 1997 (mouse)	Yes	Yes	Yes	Yes	High
Inhalation chronic exposure					
NTP 1997 (rat)	Yes	Yes	Yes	Yes	High
NTP 1997 (mouse)	Yes	Yes	Yes	Yes	High
Oral acute exposure					
Bersenyi et al. 2008 (rabbit, males)	Yes	No	Yes	Yes	Moderate
Bersenyi et al. 2008 (rabbit, females)	Yes	No	Yes	Yes	Moderate
Oral intermediate exposure					
Murray et al. 2013 (rat)	Yes	Yes	Yes	Yes	High
Rana and Chauhan 2000 (rat)	Yes	Yes	No	Yes	Moderate
Rana and Kumar 1980b (rat)	Yes	Yes	No	Yes	Moderate
Rana and Kumar 1980c (rat)	Yes	Yes	No	Yes	Moderate
Rana and Kumar 1983 (rat)	Yes	Yes	No	Yes	Moderate
Rana and Prakash 1986 (rat)	Yes	Yes	No	Yes	Moderate
Rana et al. 1980 (rat)	Yes	Yes	No	No	Low
Rana et al. 1985 (rat)	Yes	Yes	No	Yes	Moderate
Outcome: Renal effects					
Inhalation intermediate exposure					
NTP 1997 (rat)	Yes	Yes	Yes	Yes	High
NTP 1997 (mouse)	Yes	Yes	Yes	Yes	High

Table B-16. Presence of Key Features of Study Design for Molybdenum—Experimental Animal Studies

Reference	Key feature: Concurrent control group	Key feature: Sufficient number of animals per group	Key feature: Appropriate parameters to assess potential effect	Key feature: Adequate data for statistical analysis	Initial study confidence
Inhalation chronic exposure					
NTP 1997 (rat)	Yes	Yes	Yes	Yes	High
NTP 1997 (mouse)	Yes	Yes	Yes	Yes	High
Oral acute exposure					
Bersenyi et al. 2008 (rabbit, males)	Yes	No	Yes	Yes	Moderate
Bersenyi et al. 2008 (rabbit, females)	Yes	No	Yes	Yes	Moderate
Oral intermediate exposure					
Bandyopadhyay et al. 1981 (rat)	Yes	No	Yes	No	Low
Bompart et al. 1990 (rat)	Yes	No	Yes	Yes	Moderate
Murray et al. 2013 (rat)	Yes	Yes	Yes	Yes	High
Rana et al. 1980 (rat)	Yes	Yes	No	No	Low
Rana and Kumar 1980c	Yes	Yes	No	Yes	Moderate
Rana and Kumar 1983 (rat)	Yes	Yes	No	Yes	Moderate
Outcome: Alterations in Uric Acid Levels					
Oral intermediate exposure					
Murray et al. 2013 (rat)	Yes	Yes	Yes	Yes	High
Outcome: Reproductive effects					
Inhalation intermediate exposure					
NTP 1997 (rat)	Yes	Yes	Yes	Yes	High
NTP 1997 (mouse)	Yes	Yes	Yes	Yes	High
Oral acute exposure					
Zhang et al. 2013 (mouse)	Yes	Yes	No	Yes	Moderate
Zhai et al. 2013 (mouse)	Yes	Yes	No	Yes	Moderate
Bersenyi et al. 2008 (rabbit, males)	Yes	No	No	Yes	Low
Bersenyi et al. 2008 (rabbit, females)	Yes	No	No	No	Very Low
Oral intermediate exposure					
Fungwe et al. 1990 (rat)	Yes	No	Yes	Yes	Moderate
Jeter and Davis 1954 (rat, adult)	Yes	No	No	No	Very Low
Jeter and Davis 1954 (rat, weanlings)	Yes	No	No	No	Very Low
Lyubimov et al. 2004 (rat)	Yes	Yes	Yes	Yes	High
Murray et al. 2013 (rat)	Yes	Yes	Yes	Yes	High
Pandey and Singh 2002 (rat)	Yes	Yes	No	Yes	Moderate
Pandey and Singh 2002 (rat, fertility study)	Yes	Yes	Yes	Yes	High

Table B-16. Presence of Key Features of Study Design for Molybdenum—Experimental Animal Studies

Reference	Key feature: Concurrent control group	Key feature: Sufficient number of animals per group	Key feature: Appropriate parameters to assess potential effect	Key feature: Adequate data for statistical analysis	Initial study confidence
Outcome: Developmental effects					
Oral intermediate exposure					
Jeter and Davis 1954 (rat, weanling)	Yes	No	No	No	Very Low
Lyubimov et al. 2004 (rat)	Yes	Yes	Yes	Yes	High
Murray et al. 2014 (rat)	Yes	Yes	Yes	Yes	High
Pandey and Singh 2002 (rat)	Yes	Yes	Yes	Yes	High

Table B-17. Initial Confidence Rating for Molybdenum Health Effects Studies

	Initial study confidence	Initial confidence rating
Outcome: Respiratory effects		
Inhalation acute exposure		
Human studies		
Cohort studies		
Ott et al. 2004	Low	Low
Walravens et al. 1979	Very Low	
Animal studies		
NTP 1997 (rat)	High	High
NTP 1997 (mouse)	High	
Inhalation intermediate exposure		
Animal studies		
NTP 1997 (rat)	High	High
NTP 1997 (mouse)	High	
Inhalation chronic exposure		
Animal studies		
NTP 1997 (rat)	High	High
NTP 1997 (mouse)	High	
Outcome: Hepatic effects		
Human studies		
Cross-sectional studies		
Mendy et al. 2012	Low	Low
Inhalation intermediate exposure		
Animal studies		
NTP 1997 (rat)	High	High
NTP 1997 (mouse)	High	
Inhalation chronic exposure		
Animal studies		
NTP 1997 (rat)	High	High
NTP 1997 (mouse)	High	
Oral acute exposure		
Animal studies		
Bersenyi et al. 2008 (rabbit, males)	Moderate	Moderate
Bersenyi et al. 2008 (rabbit, females)	Moderate	
Oral intermediate exposure		
Animal studies		
Murray et al. 2013 (rat)	High	High
Rana and Chauhan 2000 (rat)	Moderate	
Rana and Kumar 1980b (rat)	Moderate	
Rana and Kumar 1980c (rat)	Moderate	
Rana and Kumar 1983 (rat)	Moderate	
Rana and Prakash 1986 (rat)	Moderate	
Rana et al. 1980 (rat)	Low	
Rana et al. 1985 (rat)	Moderate	

Table B-17. Initial Confidence Rating for Molybdenum Health Effects Studies

	Initial study confidence	Initial confidence rating
Outcome: Renal effects		
Inhalation intermediate exposure		
Animal studies		
NTP 1997 (rat)	High	High
NTP 1997 (mouse)	High	
Inhalation chronic exposure		
Animal studies		
NTP 1997 (rat)	High	High
NTP 1997 (mouse)	High	
Oral acute exposure		
Animal studies		
Bersenyi et al. 2008 (rabbit, males)	Moderate	Moderate
Bersenyi et al. 2008 (rabbit, females)	Moderate	
Oral intermediate exposure		
Animal studies		
Bandyopadhyay et al. 1981 (rat)	Low	High
Bompart et al. 1990 (rat)	Moderate	
Murray et al. 2013 (rat)	High	
Rana et al. 1980 (rat)	Low	
Rana and Kumar 1980c	Moderate	
Rana and Kumar 1983 (rat)	Moderate	
Outcome: Alterations in Uric Acid Levels		
Human studies		
Cross-sectional studies		
Koval'sky et al. 1961	Low	Low
Cohort studies		
Walravens et al. 1979	Very Low	Very Low
Oral acute exposure		
Human studies		
Controlled exposure		
Deosthale and Gopalan 1974	Low	Low
Oral intermediate exposure		
Animal studies		
Murray et al. 2013 (rat)	High	High
Outcome: Reproductive Effects		
Human studies		
Cross-sectional studies		
Lewis and Meeker 2015	Low	Low
Meeker et al. 2008	Low	
Meeker et al. 2010	Low	

Table B-17. Initial Confidence Rating for Molybdenum Health Effects Studies

	Initial study confidence	Initial confidence rating
Inhalation intermediate exposure		
Animal studies		
NTP 1997 (rat)	High	High
NTP 1997 (mouse)	High	
Oral acute exposure		
Animal studies		
Zhang et al. 2013 (mouse)	Moderate	Moderate
Zhai et al. 2013 (mouse)	Moderate	
Bersenyi et al. 2008 (rabbit)	Low	
Bersenyi et al. 2008 (rabbit)	Very Low	
Oral intermediate exposure		
Animal studies		
Fungwe et al. 1990 (rat)	Moderate	High
Jeter and Davis 1954 (rat, adult)	Very Low	
Jeter and Davis 1954 (rat, weanling)	Very Low	
Lyubimov et al. 2004 (rat)	High	
Murray et al. 2013 (rat)	High	
Pandey and Singh 2002 (rat)	Moderate	
Pandey and Singh 2002 (rat, fertility study)	High	
Outcome: Developmental Effects		
Human studies		
Cross-sectional studies		
Vazquez-Salas et al. 2014	Low	Low
Shirai et al. 2010	Low	
Oral intermediate exposure		
Animal studies		
Jeter and Davis 1954 (rat, weanling)	Very Low	High
Lyubimov et al. 2004 (rat)	High	
Murray et al. 2014 (rat)	High	
Pandey and Singh 2002 (rat)	High	

B.6.2 Adjustment of the Confidence Rating

The initial confidence rating was then downgraded or upgraded depending on whether there were substantial issues that would decrease or increase confidence in the body of evidence. The nine properties of the body of evidence that were considered are listed below. The summaries of the assessment of the confidence in the body of evidence for respiratory, hepatic, renal, alterations in uric acid levels, reproductive and developmental effects are presented in Table B-18. If the confidence ratings for a particular outcome were based on more than one type of human study, then the highest confidence rating was used for subsequent analyses. An overview of the confidence in the body of evidence for all health effects associated with molybdenum exposure is presented in Table B-19.

Five properties of the body of evidence were considered to determine whether the confidence rating should be downgraded:

- **Risk of bias.** Evaluation of whether there is substantial risk of bias across most of the studies examining the outcome. This evaluation used the risk of bias tier groupings for individual studies examining a particular outcome (Tables B-14, B-15, and B-16). Below are the criteria used to determine whether the initial confidence in the body of evidence for each outcome should be downgraded for risk of bias:
    - No downgrade if most studies are in the risk of bias first tier
    - Downgrade one confidence level if most studies are in the risk of bias second tier
    - Downgrade two confidence levels if most studies are in the risk of bias third tier

- **Unexplained inconsistency.** Evaluation of whether there is inconsistency or large variability in the magnitude or direction of estimates of effect across studies that cannot be explained. Below are the criteria used to determine whether the initial confidence in the body of evidence for each outcome should be downgraded for unexplained inconsistency:
    - No downgrade if there is little inconsistency across studies or if only one study evaluated the outcome
    - Downgrade one confidence level if there is variability across studies in the magnitude or direction of the effect
    - Downgrade two confidence levels if there is substantial variability across studies in the magnitude or direct of the effect

- **Indirectness.** Evaluation of four factors that can affect the applicability, generalizability, and relevance of the studies:
    - Relevance of the animal model to human health—unless otherwise indicated, studies in rats, mice, and other mammalian species are considered relevant to humans
    - Directness of the end points to the primary health outcome—examples of secondary outcomes or nonspecific outcomes include organ weight in the absence of histopathology or clinical chemistry findings in the absence of target tissue effects
    - Nature of the exposure in human studies and route of administration in animal studies—inhalation, oral, and dermal exposure routes are considered relevant unless there are compelling data to the contrary
    - Duration of treatment in animal studies and length of time between exposure and outcome assessment in animal and prospective human studies—this should be considered on an outcome-specific basis

  Below are the criteria used to determine whether the initial confidence in the body of evidence for each outcome should be downgraded for indirectness:
    - No downgrade if none of the factors are considered indirect
    - Downgrade one confidence level if one of the factors is considered indirect

    - Downgrade two confidence levels if two or more of the factors are considered indirect

- **Imprecision.** Evaluation of the narrowness of the effect size estimates and whether the studies have adequate statistical power. Data are considered imprecise when the ratio of the upper to lower 95% CIs for most studies is ≥10 for tests of ratio measures (e.g., odds ratios) and ≥100 for absolute measures (e.g., percent control response). Adequate statistical power is determined if the study can detect a potentially biologically meaningful difference between groups (20% change from control response for categorical data or risk ratio of 1.5 for continuous data). Below are the criteria used to determine whether the initial confidence in the body of evidence for each outcome should be downgraded for imprecision:
    - No downgrade if there are no serious imprecisions
    - Downgrade one confidence level for serious imprecisions
    - Downgrade two confidence levels for very serious imprecisions

- **Publication bias.** Evaluation of the concern that studies with statistically significant results are more likely to be published than studies without statistically significant results.
    - Downgrade one level of confidence for cases where there is serious concern with publication bias

Four properties of the body of evidence were considered to determine whether the confidence rating should be upgraded:

- **Large magnitude of effect.** Evaluation of whether the magnitude of effect is sufficiently large so that it is unlikely to have occurred as a result of bias from potential confounding factors.
    - Upgrade one confidence level if there is evidence of a large magnitude of effect in a few studies, provided that the studies have an overall low risk of bias and there is no serious unexplained inconsistency among the studies of similar dose or exposure levels; confidence can also be upgraded if there is one study examining the outcome, provided that the study has an overall low risk of bias

- **Dose response.** Evaluation of the dose-response relationships measured within a study and across studies. Below are the criteria used to determine whether the initial confidence in the body of evidence for each outcome should be upgraded:
    - Upgrade one confidence level for evidence of a monotonic dose-response gradient
    - Upgrade one confidence level for evidence of a non-monotonic dose-response gradient where there is prior knowledge that supports a non-monotonic dose-response and a non-monotonic dose-response gradient is observed across studies

- **Plausible confounding or other residual biases.** This factor primarily applies to human studies and is an evaluation of unmeasured determinants of an outcome such as residual bias towards the null (e.g., "healthy worker" effect) or residual bias suggesting a spurious effect (e.g., recall bias). Below is the criterion used to determine whether the initial confidence in the body of evidence for each outcome should be upgraded:
    - Upgrade one confidence level for evidence that residual confounding or bias would underestimate an apparent association or treatment effect (i.e., bias toward the null) or suggest a spurious effect when results suggest no effect

- **Consistency in the body of evidence.** Evaluation of consistency across animal models and species, consistency across independent studies of different human populations and exposure scenarios, and consistency across human study types. Below is the criterion used to determine whether the initial confidence in the body of evidence for each outcome should be upgraded:

- Upgrade one confidence level if there is a high degree of consistency in the database

Table B-18. Adjustments to the Initial Confidence in the Body of Evidence

	Initial confidence	Adjustments to the initial confidence rating	Final confidence
Outcome: Respiratory Effects			
Cohort studies	Low	-1 risk of bias; -1 imprecision	Very low
Animal studies	High	+1 magnitude	High
Outcome: Hepatic Effects			
Cross-sectional studies	Low	-1 risk of bias	Very low
Animal studies	High	-1 indirectness (secondary outcomes);	Moderate
Outcome: Renal Effects			
Animal studies	High	None	High
Outcome: Alterations in Uric Acid Levels			
Cross-sectional studies	Low	-1 risk of bias	Very low
Cohort studies	Very Low	-1 risk of bias	Very low
Human controlled exposure studies	Low	None	Low
Animal studies	High	None	High
Outcome: Reproductive Effects			
Cross-sectional studies	Low	None	Low
Animal studies	High	-1 inconsistency	Moderate
Outcome: Developmental Effects			
Cross-sectional studies	Low	None	Low
Animal studies	High	-1 inconsistency	Moderate

Table B-19. Confidence in the Body of Evidence for Molybdenum

	Confidence in body of evidence	
Outcome	Human studies	Animal studies
Respiratory effects	Very low	High
Hepatic effects	Very low	Moderate
Renal effects	No data	High
Alterations in uric acid levels	Low	High
Reproductive Effects	Low	Moderate
Developmental effects	Low	Moderate

B.7 TRANSLATE CONFIDENCE RATING INTO LEVEL OF EVIDENCE OF HEALTH EFFECTS

In the seventh step of the systematic review of the health effects data for molybdenum, the confidence in the body of evidence for specific outcomes was translated to a level of evidence rating. The level of evidence rating reflected the confidence in the body of evidence and the direction of the effect (i.e., toxicity or no toxicity); route-specific differences were noted. The level of evidence for health effects was rated on a five-point scale:

- **High level of evidence:** High confidence in the body of evidence for an association between exposure to the substance and the health outcome
- **Moderate level of evidence:** Moderate confidence in the body of evidence for an association between exposure to the substance and the health outcome
- **Low level of evidence:** Low confidence in the body of evidence for an association between exposure to the substance and the health outcome
- **Evidence of no health effect:** High confidence in the body of evidence that exposure to the substance is not associated with the health outcome
- **Inadequate evidence:** Low or moderate confidence in the body of evidence that exposure to the substance is not associated with the health outcome or very low confidence in the body of evidence for an association between exposure to the substance and the health outcome

A summary of the level of evidence of health effects for molybdenum is presented in Table B-20.

Table B-20. Level of Evidence of Health Effects for Molybdenum

Outcome	Confidence in body of evidence	Direction of health effect	Level of evidence for health effect
Human studies			
Respiratory effects (inhalation only)	Very low	Health effect	Inadequate
Hepatic effects	Very low	Health effect	Inadequate
Renal effects	No data	No data	No data
Alterations in uric acid levels	Low	Health effect	Inadequate
Reproductive effects	Low	Health effect	Low
Developmental effects	Low	Health effect	Low
Animal studies			
Respiratory effects (inhalation only)	High	Health effect	High
Hepatic effects	Moderate	Health effect	Moderate
Renal effects	High	Health effect	High
Alterations in uric acid levels	High	No effect	Evidence of no health effect
Reproductive effects	Moderate	Health effect	Moderate
Developmental effects[a]	Moderate	Health effect No health effect	High Evidence of no health effect

[a]Mixed results were found in animal studies reporting developmental effects; three studies reported no effects and one study reported an effect.

B.8 INTEGRATE EVIDENCE TO DEVELOP HAZARD IDENTIFICATION CONCLUSIONS

The final step involved the integration of the evidence streams for the human studies and animal studies to allow for a determination of hazard identification conclusions. For health effects, there were four hazard identification conclusion categories:

- **Known** to be a hazard to humans
- **Presumed** to be a hazard to humans
- **Suspected** to be a hazard to humans
- **Not classifiable** as to the hazard to humans

The initial hazard identification was based on the highest level of evidence in the human studies and the level of evidence in the animal studies; if there were no data for one evidence stream (human or animal), then the hazard identification was based on the one data stream (equivalent to treating the missing evidence stream as having low level of evidence). The hazard identification scheme is presented in Figure B-2 and described below:

- **Known:** A health effect in this category would have:
  - o High level of evidence for health effects in human studies **AND** a high, moderate, or low level of evidence in animal studies.

- **Presumed:** A health effect in this category would have:
    - o Moderate level of evidence in human studies **AND** high or moderate level of evidence in animal studies **OR**
    - o Low level of evidence in human studies **AND** high level of evidence in animal studies
- **Suspected:** A health effect in this category would have:
    - o Moderate level of evidence in human studies **AND** low level of evidence in animal studies **OR**
    - o Low level of evidence in human studies **AND** moderate level of evidence in animal studies
- **Not classifiable:** A health effect in this category would have:
    - o Low level of evidence in human studies **AND** low level of evidence in animal studies

Other relevant data such as mechanistic or mode-of-action data were considered to raise or lower the level of the hazard identification conclusion by providing information that supported or opposed biological plausibility.

Two hazard identification conclusion categories were used when the data indicated that there may be no health effect in humans:

- **Not identified** to be a hazard in humans
- **Inadequate** to determine hazard to humans

If the human level of evidence conclusion of no health effect was supported by the animal evidence of no health effect, then the hazard identification conclusion category of "not identified" was used. If the human or animal level of evidence was considered inadequate, then a hazard identification conclusion category of "inadequate" was used. As with the hazard identification for health effects, the impact of other relevant data was also considered for no health effect data.

The hazard identification conclusions for molybdenum are listed below and summarized in Table B-21.

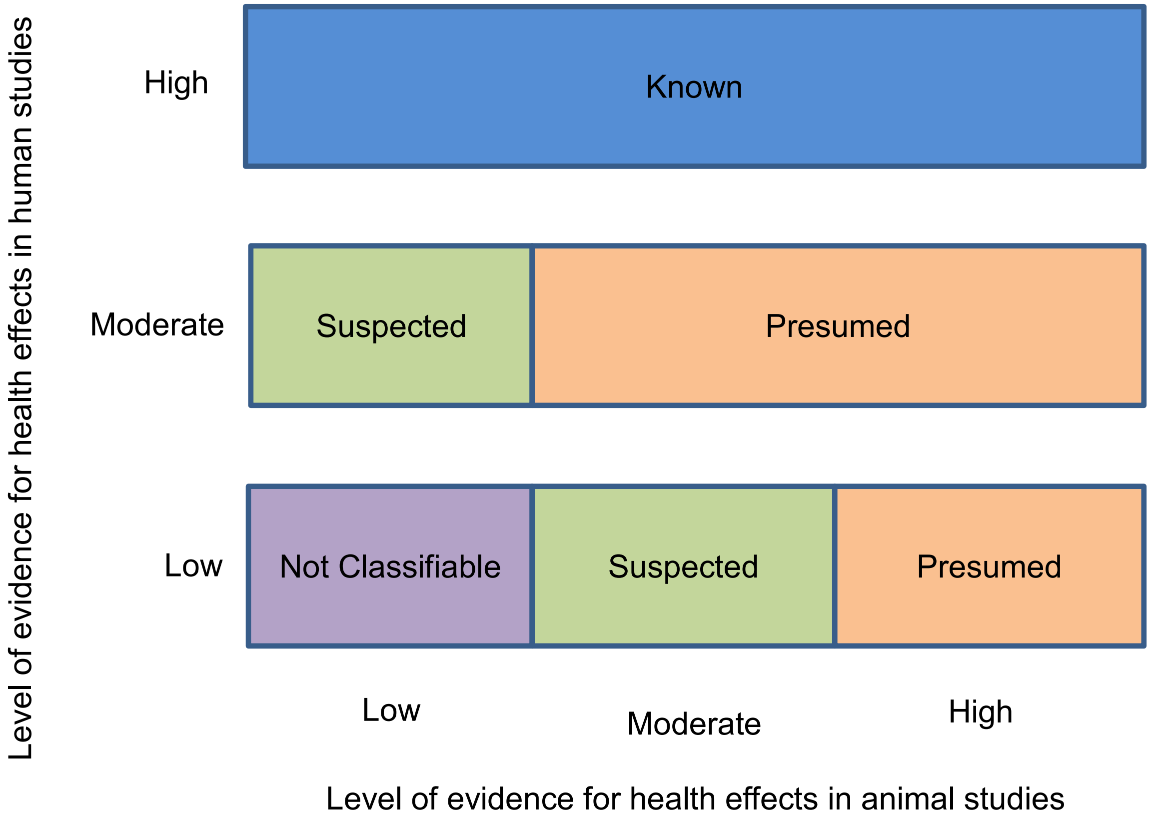
Presumed Health Effects

- Respiratory effects following inhalation exposure to molybdenum oxides
    - o Inadequate evidence from studies of molybdenum oxide workers (Ott et al. 2004; Walravens et al. 1979).
    - o High level of evidence from chronic exposure studies in rats and mice (NTP 1997).
- Renal effects
    - o No data in humans.
    - o High level of evidence of histological alterations in kidneys, alterations in renal function, and/or increased lipid levels in the kidneys in orally exposed rats (Bandyopadhyay et al. 1981; Bompart et al. 1990; Murray et al. 2013; Rana and Kumar 1980c, 1983; Rana et al. 1980).

Table B-21. Hazard Identification Conclusions for Molybdenum

Outcome	Hazard identification
Respiratory effects	Presumed health effect following inhalation exposure
Hepatic effects	Suspected health effect
Renal effects	Presumed health effect
Alterations in uric acid levels	Not classifiable as a hazard to humans
Reproductive effects	Suspected health effect
Developmental effects	Not classifiable as a hazard to humans

Figure B-2. Hazard Identification Scheme



Suspected Health Effects

- Hepatic effects
  - Inadequate evidence of increased risk of self-reported liver conditions from a cross-sectional study (Mendy et al. 2012).
  - Moderate evidence of increases in clinical chemistry parameters and/or liver lipid levels in rabbits following acute oral exposure (Bersenyi et al. 2008) or rats exposed orally exposed to high doses (Rana and Chauhan 2000; Rana and Kumar 1980b, 1980c, 1983; Rana and Prakash 1986; Rana et al. 1980, 1985).
- Reproductive effects
  - Low level of evidence of male reproductive effects in cross-sectional studies (Lewis and Meeker 2015; Meeker et al. 2008, 2010).
  - Moderate level of evidence of male and/or female reproductive effects in orally exposed rats (Fungwe et al. 1990; Lyubimov et al. 2004; Murray et al. 2013; Pandey and Singh 2002), mice (Zhai et al. 2013; Zhang et al. 2013), and rabbits (Bersenyi et al. 2008).

Not Classifiable as a Hazard to Humans

- Alterations in uric acid levels
  - Low evidence of an effect in cross-sectional studies (Koval'skiy et al. 1961; Walravens et al. 1979).
  - High confidence in an animal study not finding an effect (Murray et al. 2013).
- Developmental effects
  - Low evidence of an effect in a cross-sectional study. Two cross-sectional studies reported no alterations in newborn body weight (Shirai et al. 2010; Vazquez-Salas et al. 2014); one study reported decreases in psychomotor development indices (Vazquez-Salas et al. 2014).
  - Three studies in rats did not find alterations in resorptions, post-implantation losses, or fetal body weights (Jeter and Davis 1954; Lyubimov et al. 2004; Murray et al. 2014); the initial confidence levels for these studies were high, high, and very low. A fourth study (initial high confidence level) involving male-only exposure found decreases in number of live fetuses and fetal body weights (Pandey and Singh 2002).
  - The animal studies had different study designs (male only, female only, male and female exposure) making a comparison across studies difficult. Additionally, none of the animal studies evaluated potential neurodevelopmental effects, which were observed in an epidemiology study. Thus, the available data were not considered adequate for drawing a conclusion on the potential developmental toxicity of molybdenum in humans.

APPENDIX C. USER'S GUIDE

Chapter 1

Public Health Statement

This chapter of the profile is a health effects summary written in non-technical language. Its intended audience is the general public, especially people living in the vicinity of a hazardous waste site or chemical release. If the Public Health Statement were removed from the rest of the document, it would still communicate to the lay public essential information about the chemical.

The major headings in the Public Health Statement are useful to find specific topics of concern. The topics are written in a question and answer format. The answer to each question includes a sentence that will direct the reader to chapters in the profile that will provide more information on the given topic.

Chapter 2

Relevance to Public Health

This chapter provides a health effects summary based on evaluations of existing toxicologic, epidemiologic, and toxicokinetic information. This summary is designed to present interpretive, weight-of-evidence discussions for human health end points by addressing the following questions:

1. What effects are known to occur in humans?
2. What effects observed in animals are likely to be of concern to humans?
3. What exposure conditions are likely to be of concern to humans, especially around hazardous waste sites?

The chapter covers end points in the same order that they appear within the Discussion of Health Effects by Route of Exposure section, by route (inhalation, oral, and dermal) and within route by effect. Human data are presented first, then animal data. Both are organized by duration (acute, intermediate, chronic). *In vitro* data and data from parenteral routes (intramuscular, intravenous, subcutaneous, etc.) are also considered in this chapter.

The carcinogenic potential of the profiled substance is qualitatively evaluated, when appropriate, using existing toxicokinetic, genotoxic, and carcinogenic data. ATSDR does not currently assess cancer potency or perform cancer risk assessments. Minimal Risk Levels (MRLs) for noncancer end points (if derived) and the end points from which they were derived are indicated and discussed.

Limitations to existing scientific literature that prevent a satisfactory evaluation of the relevance to public health are identified in the Chapter 3 Data Needs section.

Interpretation of Minimal Risk Levels

Where sufficient toxicologic information is available, ATSDR has derived MRLs for inhalation and oral routes of entry at each duration of exposure (acute, intermediate, and chronic). These MRLs are not meant to support regulatory action, but to acquaint health professionals with exposure levels at which adverse health effects are not expected to occur in humans.

MRLs should help physicians and public health officials determine the safety of a community living near a hazardous substance emission, given the concentration of a contaminant in air or the estimated daily dose in water. MRLs are based largely on toxicological studies in animals and on reports of human occupational exposure.

MRL users should be familiar with the toxicologic information on which the number is based. Chapter 2, "Relevance to Public Health," contains basic information known about the substance. Other sections such as Chapter 3 Section 3.9, "Interactions with Other Substances," and Section 3.10, "Populations that are Unusually Susceptible" provide important supplemental information.

MRL users should also understand the MRL derivation methodology. MRLs are derived using a modified version of the risk assessment methodology that the Environmental Protection Agency (EPA) provides (Barnes and Dourson 1988) to determine reference doses (RfDs) for lifetime exposure.

To derive an MRL, ATSDR generally selects the most sensitive end point which, in its best judgement, represents the most sensitive human health effect for a given exposure route and duration. ATSDR cannot make this judgement or derive an MRL unless information (quantitative or qualitative) is available for all potential systemic, neurological, and developmental effects. If this information and reliable quantitative data on the chosen end point are available, ATSDR derives an MRL using the most sensitive species (when information from multiple species is available) with the highest no-observed-adverse-effect level (NOAEL) that does not exceed any adverse effect levels. When a NOAEL is not available, a lowest-observed-adverse-effect level (LOAEL) can be used to derive an MRL, and an uncertainty factor (UF) of 10 must be employed. Additional uncertainty factors of 10 must be used both for human variability to protect sensitive subpopulations (people who are most susceptible to the health effects caused by the substance) and for interspecies variability (extrapolation from animals to humans). In deriving an MRL, these individual uncertainty factors are multiplied together. The product is then divided into the inhalation concentration or oral dosage selected from the study. Uncertainty factors used in developing a substance-specific MRL are provided in the footnotes of the levels of significant exposure (LSE) tables.

Chapter 3

Health Effects

Tables and Figures for Levels of Significant Exposure (LSE)

Tables and figures are used to summarize health effects and illustrate graphically levels of exposure associated with those effects. These levels cover health effects observed at increasing dose concentrations and durations, differences in response by species, MRLs to humans for noncancer end points, and EPA's estimated range associated with an upper- bound individual lifetime cancer risk of 1 in 10,000 to 1 in 10,000,000. Use the LSE tables and figures for a quick review of the health effects and to locate data for a specific exposure scenario. The LSE tables and figures should always be used in conjunction with the text. All entries in these tables and figures represent studies that provide reliable, quantitative estimates of NOAELs, LOAELs, or Cancer Effect Levels (CELs).

The legends presented below demonstrate the application of these tables and figures. Representative examples of LSE Table 3-1 and Figure 3-1 are shown. The numbers in the left column of the legends correspond to the numbers in the example table and figure.

LEGEND

See Sample LSE Table 3-1 (page C-6)

(1) Route of Exposure. One of the first considerations when reviewing the toxicity of a substance using these tables and figures should be the relevant and appropriate route of exposure. Typically when sufficient data exist, three LSE tables and two LSE figures are presented in the document. The three LSE tables present data on the three principal routes of exposure, i.e., inhalation, oral, and dermal (LSE Tables 3-1, 3-2, and 3-3, respectively). LSE figures are limited to the inhalation (LSE Figure 3-1) and oral (LSE Figure 3-2) routes. Not all substances will have data on each route of exposure and will not, therefore, have all five of the tables and figures.

(2) Exposure Period. Three exposure periods—acute (less than 15 days), intermediate (15–364 days), and chronic (365 days or more)—are presented within each relevant route of exposure. In this example, an inhalation study of intermediate exposure duration is reported. For quick reference to health effects occurring from a known length of exposure, locate the applicable exposure period within the LSE table and figure.

(3) Health Effect. The major categories of health effects included in LSE tables and figures include death, systemic, immunological, neurological, developmental, reproductive, and cancer. NOAELs and LOAELs can be reported in the tables and figures for all effects but cancer. Systemic effects are further defined in the "System" column of the LSE table (see key number 18).

(4) Key to Figure. Each key number in the LSE table links study information to one or more data points using the same key number in the corresponding LSE figure. In this example, the study represented by key number 18 has been used to derive a NOAEL and a Less Serious LOAEL (also see the two "18r" data points in sample Figure 3-1).

(5) Species. The test species, whether animal or human, are identified in this column. Chapter 2, "Relevance to Public Health," covers the relevance of animal data to human toxicity and Section 3.4, "Toxicokinetics," contains any available information on comparative toxicokinetics. Although NOAELs and LOAELs are species specific, the levels are extrapolated to equivalent human doses to derive an MRL.

(6) Exposure Frequency/Duration. The duration of the study and the weekly and daily exposure regimens are provided in this column. This permits comparison of NOAELs and LOAELs from different studies. In this case (key number 18), rats were exposed to "Chemical x" via inhalation for 6 hours/day, 5 days/week, for 13 weeks. For a more complete review of the dosing regimen, refer to the appropriate sections of the text or the original reference paper (i.e., Nitschke et al. 1981).

(7) System. This column further defines the systemic effects. These systems include respiratory, cardiovascular, gastrointestinal, hematological, musculoskeletal, hepatic, renal, and dermal/ocular. "Other" refers to any systemic effect (e.g., a decrease in body weight) not covered in these systems. In the example of key number 18, one systemic effect (respiratory) was investigated.

(8) NOAEL. A NOAEL is the highest exposure level at which no adverse effects were seen in the organ system studied. Key number 18 reports a NOAEL of 3 ppm for the respiratory system, which was used to derive an intermediate exposure, inhalation MRL of 0.005 ppm (see footnote "b").

(9) LOAEL. A LOAEL is the lowest dose used in the study that caused an adverse health effect. LOAELs have been classified into "Less Serious" and "Serious" effects. These distinctions help readers identify the levels of exposure at which adverse health effects first appear and the gradation of effects with increasing dose. A brief description of the specific end point used to quantify the adverse effect accompanies the LOAEL. The respiratory effect reported in key number 18 (hyperplasia) is a Less Serious LOAEL of 10 ppm. MRLs are not derived from Serious LOAELs.

(10) Reference. The complete reference citation is given in Chapter 9 of the profile.

(11) CEL. A CEL is the lowest exposure level associated with the onset of carcinogenesis in experimental or epidemiologic studies. CELs are always considered serious effects. The LSE tables and figures do not contain NOAELs for cancer, but the text may report doses not causing measurable cancer increases.

(12) Footnotes. Explanations of abbreviations or reference notes for data in the LSE tables are found in the footnotes. Footnote "b" indicates that the NOAEL of 3 ppm in key number 18 was used to derive an MRL of 0.005 ppm.

LEGEND

See Sample Figure 3-1 (page C-7)

LSE figures graphically illustrate the data presented in the corresponding LSE tables. Figures help the reader quickly compare health effects according to exposure concentrations for particular exposure periods.

(13) Exposure Period. The same exposure periods appear as in the LSE table. In this example, health effects observed within the acute and intermediate exposure periods are illustrated.

(14) Health Effect. These are the categories of health effects for which reliable quantitative data exists. The same health effects appear in the LSE table.

(15) Levels of Exposure. Concentrations or doses for each health effect in the LSE tables are graphically displayed in the LSE figures. Exposure concentration or dose is measured on the log scale "y" axis. Inhalation exposure is reported in mg/m^3 or ppm and oral exposure is reported in mg/kg/day.

(16) NOAEL. In this example, the open circle designated 18r identifies a NOAEL critical end point in the rat upon which an intermediate inhalation exposure MRL is based. The key number 18 corresponds to the entry in the LSE table. The dashed descending arrow indicates the extrapolation from the exposure level of 3 ppm (see entry 18 in the table) to the MRL of 0.005 ppm (see footnote "b" in the LSE table).

(17) CEL. Key number 38m is one of three studies for which CELs were derived. The diamond symbol refers to a CEL for the test species-mouse. The number 38 corresponds to the entry in the LSE table.

(18) Estimated Upper-Bound Human Cancer Risk Levels. This is the range associated with the upper-bound for lifetime cancer risk of 1 in 10,000 to 1 in 10,000,000. These risk levels are derived from the EPA's Human Health Assessment Group's upper-bound estimates of the slope of the cancer dose response curve at low dose levels (q_1*).

(19) Key to LSE Figure. The Key explains the abbreviations and symbols used in the figure.

SAMPLE

1 → **Table 3-1. Levels of Significant Exposure to [Chemical x] – Inhalation**

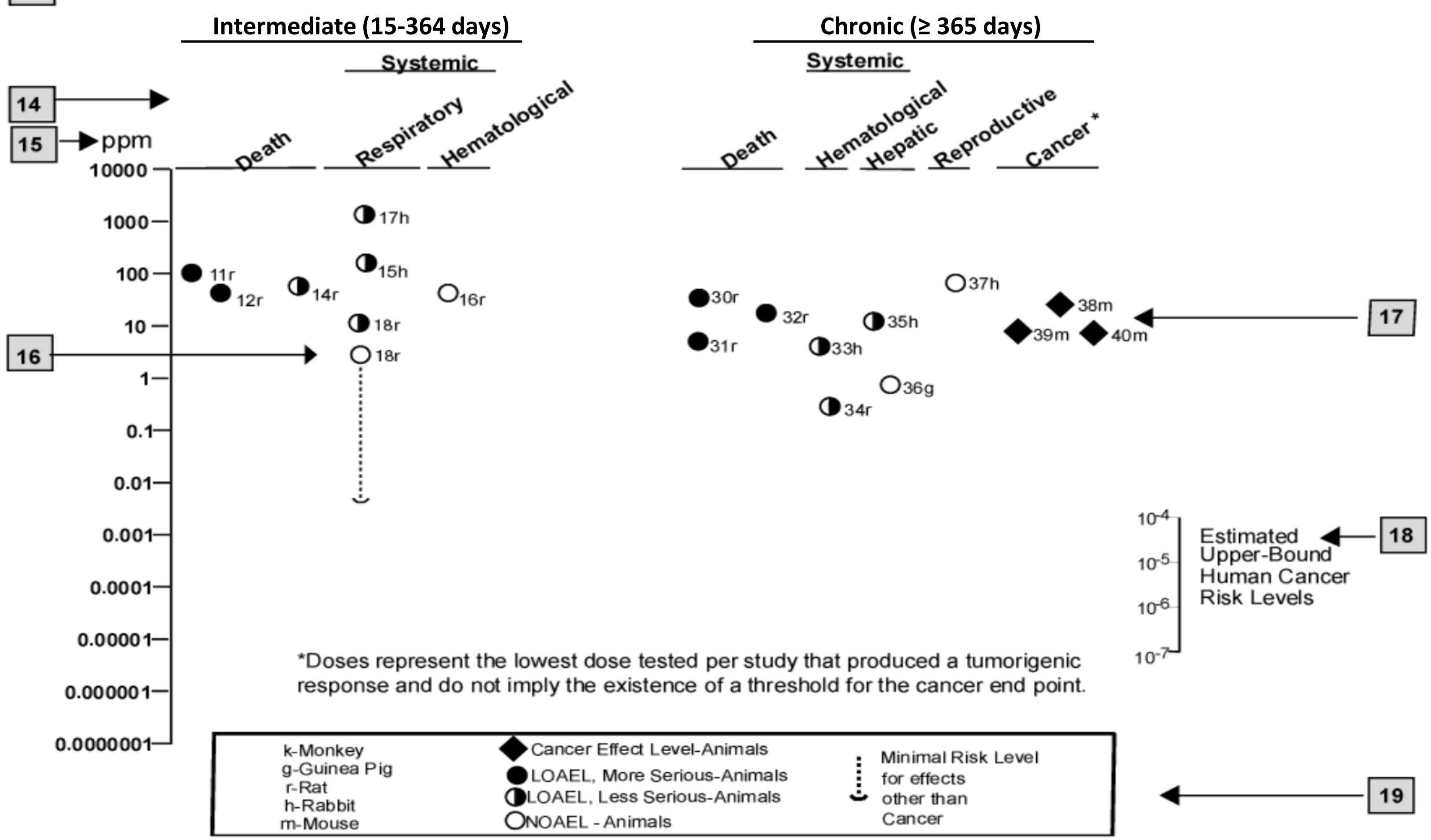
	Key to figure[a]	Species	Exposure frequency/ duration	System	NOAEL (ppm)	LOAEL (effect) Less serious (ppm)	Serious (ppm)	Reference
2 →	INTERMEDIATE EXPOSURE							
		5 ↓	6 ↓	7 ↓	8 ↓	9 ↓		10 ↓
3 →	Systemic							
4 →	18	Rat	13 wk 5 d/wk 6 hr/d	Resp	3[b]	10 (hyperplasia)		Nitschke et al. 1981
	CHRONIC EXPOSURE							
	Cancer						11 ↓	
	38	Rat	18 mo 5 d/wk 7 hr/d				20 (CEL, multiple organs)	Wong et al. 1982
	39	Rat	89–104 wk 5 d/wk 6 hr/d				10 (CEL, lung tumors, nasal tumors)	NTP 1982
	40	Mouse	79–103 wk 5 d/wk 6 hr/d				10 (CEL, lung tumors, hemangiosarcomas)	NTP 1982

12 → [a] The number corresponds to entries in Figure 3-1.
[b] Used to derive an intermediate inhalation Minimal Risk Level (MRL) of 5×10^{-3} ppm; dose adjusted for intermittent exposure and divided by an uncertainty factor of 100 (10 for extrapolation from animal to humans, 10 for human variability).

SAMPLE

13

Figure 3-1. Levels of Significant Exposure to [Chemical X] - Inhalation



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APPENDIX D. ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ACGIH	American Conference of Governmental Industrial Hygienists
ACOEM	American College of Occupational and Environmental Medicine
ADI	acceptable daily intake
ADME	absorption, distribution, metabolism, and excretion
AED	atomic emission detection
AFID	alkali flame ionization detector
AFOSH	Air Force Office of Safety and Health
ALT	alanine aminotransferase
AML	acute myeloid leukemia
AOAC	Association of Official Analytical Chemists
AOEC	Association of Occupational and Environmental Clinics
AP	alkaline phosphatase
APHA	American Public Health Association
AST	aspartate aminotransferase
atm	atmosphere
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient Water Quality Criteria
BAT	best available technology
BCF	bioconcentration factor
BEI	Biological Exposure Index
BMD/C	benchmark dose or benchmark concentration
BMD_X	dose that produces a X% change in response rate of an adverse effect
$BMDL_X$	95% lower confidence limit on the BMD_X
BMDS	Benchmark Dose Software
BMR	benchmark response
BSC	Board of Scientific Counselors
C	centigrade
CAA	Clean Air Act
CAG	Cancer Assessment Group of the U.S. Environmental Protection Agency
CAS	Chemical Abstract Services
CDC	Centers for Disease Control and Prevention
CEL	cancer effect level
CELDS	Computer-Environmental Legislative Data System
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	curie
CI	confidence interval
CLP	Contract Laboratory Program
cm	centimeter
CML	chronic myeloid leukemia
CPSC	Consumer Products Safety Commission
CWA	Clean Water Act
DHEW	Department of Health, Education, and Welfare
DHHS	Department of Health and Human Services
DNA	deoxyribonucleic acid
DOD	Department of Defense
DOE	Department of Energy
DOL	Department of Labor
DOT	Department of Transportation

DOT/UN/ NA/IMDG	Department of Transportation/United Nations/ North America/Intergovernmental Maritime Dangerous Goods Code
DWEL	drinking water exposure level
ECD	electron capture detection
ECG/EKG	electrocardiogram
EEG	electroencephalogram
EEGL	Emergency Exposure Guidance Level
EPA	Environmental Protection Agency
F	Fahrenheit
F_1	first-filial generation
FAO	Food and Agricultural Organization of the United Nations
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FPD	flame photometric detection
fpm	feet per minute
FR	Federal Register
FSH	follicle stimulating hormone
g	gram
GC	gas chromatography
gd	gestational day
GLC	gas liquid chromatography
GPC	gel permeation chromatography
HPLC	high-performance liquid chromatography
HRGC	high resolution gas chromatography
HSDB	Hazardous Substance Data Bank
IARC	International Agency for Research on Cancer
IDLH	immediately dangerous to life and health
ILO	International Labor Organization
IRIS	Integrated Risk Information System
Kd	adsorption ratio
kg	kilogram
kkg	kilokilogram; 1 kilokilogram is equivalent to 1,000 kilograms and 1 metric ton
K_{oc}	organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient
L	liter
LC	liquid chromatography
LC_{50}	lethal concentration, 50% kill
LC_{Lo}	lethal concentration, low
LD_{50}	lethal dose, 50% kill
LD_{Lo}	lethal dose, low
LDH	lactic dehydrogenase
LH	luteinizing hormone
LOAEL	lowest-observed-adverse-effect level
LSE	Levels of Significant Exposure
LT_{50}	lethal time, 50% kill
m	meter
MA	*trans,trans*-muconic acid
MAL	maximum allowable level
mCi	millicurie
MCL	maximum contaminant level

MCLG	maximum contaminant level goal
MF	modifying factor
MFO	mixed function oxidase
mg	milligram
mL	milliliter
mm	millimeter
mmHg	millimeters of mercury
mmol	millimole
mppcf	millions of particles per cubic foot
MRL	Minimal Risk Level
MS	mass spectrometry
mt	metric ton
NAAQS	National Ambient Air Quality Standard
NAS	National Academy of Science
NATICH	National Air Toxics Information Clearinghouse
NATO	North Atlantic Treaty Organization
NCE	normochromatic erythrocytes
NCEH	National Center for Environmental Health
NCI	National Cancer Institute
ND	not detected
NFPA	National Fire Protection Association
ng	nanogram
NHANES	National Health and Nutrition Examination Survey
NIEHS	National Institute of Environmental Health Sciences
NIOSH	National Institute for Occupational Safety and Health
NIOSHTIC	NIOSH's Computerized Information Retrieval System
NLM	National Library of Medicine
nm	nanometer
nmol	nanomole
NOAEL	no-observed-adverse-effect level
NOES	National Occupational Exposure Survey
NOHS	National Occupational Hazard Survey
NPD	nitrogen phosphorus detection
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NR	not reported
NRC	National Research Council
NS	not specified
NSPS	New Source Performance Standards
NTIS	National Technical Information Service
NTP	National Toxicology Program
ODW	Office of Drinking Water, EPA
OERR	Office of Emergency and Remedial Response, EPA
OHM/TADS	Oil and Hazardous Materials/Technical Assistance Data System
OPP	Office of Pesticide Programs, EPA
OPPT	Office of Pollution Prevention and Toxics, EPA
OPPTS	Office of Prevention, Pesticides and Toxic Substances, EPA
OR	odds ratio
OSHA	Occupational Safety and Health Administration
OSW	Office of Solid Waste, EPA
OTS	Office of Toxic Substances

OW	Office of Water
OWRS	Office of Water Regulations and Standards, EPA
PAH	polycyclic aromatic hydrocarbon
PBPD	physiologically based pharmacodynamic
PBPK	physiologically based pharmacokinetic
PCE	polychromatic erythrocytes
PEL	permissible exposure limit
PEL-C	permissible exposure limit-ceiling value
pg	picogram
PHS	Public Health Service
PID	photo ionization detector
pmol	picomole
PMR	proportionate mortality ratio
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
PSNS	pretreatment standards for new sources
RBC	red blood cell
REL	recommended exposure level/limit
REL-C	recommended exposure level-ceiling value
RfC	reference concentration (inhalation)
RfD	reference dose (oral)
RNA	ribonucleic acid
RQ	reportable quantity
RTECS	Registry of Toxic Effects of Chemical Substances
SARA	Superfund Amendments and Reauthorization Act
SCE	sister chromatid exchange
SGOT	serum glutamic oxaloacetic transaminase (same as aspartate aminotransferase or AST)
SGPT	serum glutamic pyruvic transaminase (same as alanine aminotransferase or ALT)
SIC	standard industrial classification
SIM	selected ion monitoring
SMCL	secondary maximum contaminant level
SMR	standardized mortality ratio
SNARL	suggested no adverse response level
SPEGL	Short-Term Public Emergency Guidance Level
STEL	short term exposure limit
STORET	Storage and Retrieval
TD_{50}	toxic dose, 50% specific toxic effect
TLV	threshold limit value
TLV-C	threshold limit value-ceiling value
TOC	total organic carbon
TPQ	threshold planning quantity
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
TWA	time-weighted average
UF	uncertainty factor
U.S.	United States
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VOC	volatile organic compound
WBC	white blood cell

WHO	World Health Organization
>	greater than
≥	greater than or equal to
=	equal to
<	less than
≤	less than or equal to
%	percent
α	alpha
β	beta
γ	gamma
δ	delta
μm	micrometer
μg	microgram
q_1^*	cancer slope factor
–	negative
+	positive
(+)	weakly positive result
(–)	weakly negative result

C2 Addendum No. 1, Assessment of Corrective Measures (November 2020)

Addendum No. 1
Assessment of Corrective Measures
Existing Surface Impoundments

Burlington Generating Station
Burlington, Iowa

Prepared for:

Alliant Energy

SCS ENGINEERS

25219168.00 | November 24, 2020

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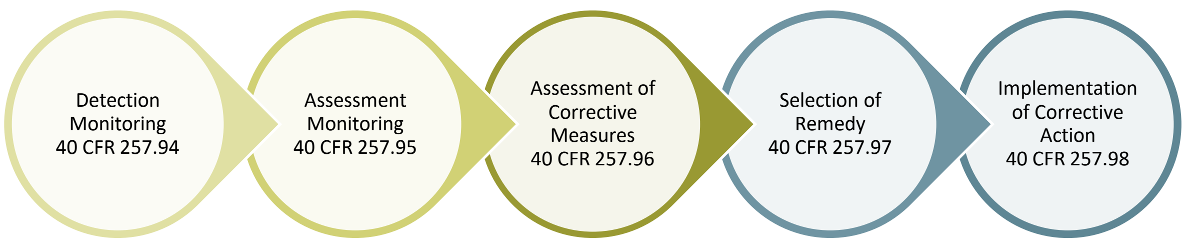
EXECUTIVE SUMMARY

Interstate Power and Light Company (IPL), an Alliant Energy company, operates four ash ponds at the Burlington Generating Station (BGS). The ponds are used to manage coal combustion residuals (CCR) and wastewater from the power plant, which burns coal and natural gas to generate electricity.

IPL samples and tests the groundwater in the area of the ash ponds to comply with U.S. Environmental Protection Agency (USEPA) standards for the Disposal of CCR from Electric Utilities, or the "CCR Rule" (Rule). Groundwater samples from some of the wells installed to monitor the ash ponds contained two metals, lithium and molybdenum, at levels higher than the Groundwater Protection Standards (GPS) defined in the Rule. These metals occur naturally, and both can be present in coal and CCR.

IPL prepared an Assessment of Corrective Measures (ACM) Report in September 2019 in response to the groundwater sampling results at the BGS facility. The ACM process is one step in a series of steps defined in the Rule and shown below.



To prepare the ACM, IPL worked to understand the following:

- Types of soil and rock deposits in the area of the BGS facility.
- Depth of groundwater.
- Direction that groundwater is moving.
- Potential sources of the lithium and molybdenum in groundwater.
- The area where lithium and molybdenum levels are higher than the USEPA standards.
- The people, plants, and animals that may be affected by levels of lithium and molybdenum in groundwater that are above the GPS.

Because the time allowed by the Rule to prepare the ACM was limited, IPL has continued work to improve the understanding of the items listed above. Addendum No. 1 has been prepared to update the ACM for BGS based on the information now available.

IPL has identified and evaluated additional Corrective Measures to bring the levels of lithium and molybdenum in groundwater below USEPA standards. In addition to stopping the discharge of CCR and BGS wastewater to the ponds, these corrective measures include:

- Cap CCR in Place with Monitored Natural Attenuation (MNA)
- Consolidate CCR and Cap with MNA
- Excavate and Dispose CCR On-Site with MNA
- Excavate and Dispose CCR in Off-site Landfill with MNA

- Consolidate and Cap with Chemical Amendment
- Consolidate and Cap with Groundwater Collection
- Consolidate and Cap with Barrier Wall

IPL has also included a "No Action" alternative for comparison purposes only. This alternative will not be selected as a remedy.

Addendum No. 1 includes an updated evaluation that includes all eight options using factors identified in the Rule.

IPL will provide semiannual updates on its progress in evaluating Corrective Measures to address the groundwater impacts at BGS.

IPL held a public meeting on October 14, 2020, to discuss the contents of the September 2019 ACM. Before a remedy is selected, IPL will hold a public meeting with interested and affected parties to discuss this addendum.

For more information on Alliant Energy, view our Corporate Responsibility Report at https://poweringwhatsnext.alliantenergy.com/crr/.

1.0 INTRODUCTION AND PURPOSE

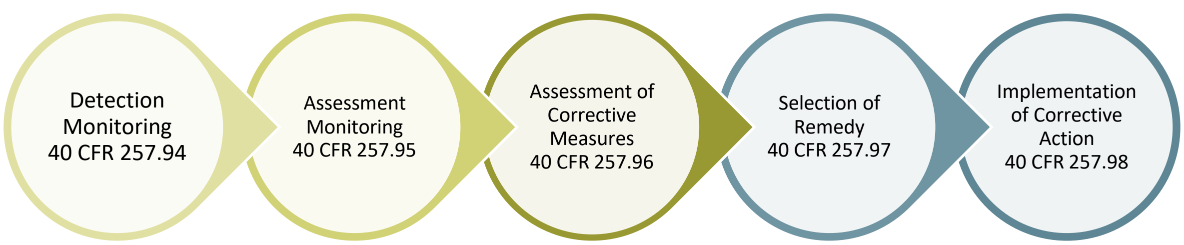
An Assessment of Corrective Measures (ACM) at the Interstate Power and Light Company (IPL) Burlington Generating Station (BGS) was prepared to comply with U.S. Environmental Protection Agency (USEPA) regulations regarding the Disposal of Coal Combustion Residuals (CCR) from Electric Utilities [40 CFR 257.50-107], or the "CCR Rule"(Rule). Specifically, the ACM was initiated and this report was prepared to fulfill the requirements of 40 CFR 257.96, including:

- Prevention of further releases
- Remediation of release
- Restoration of affected areas

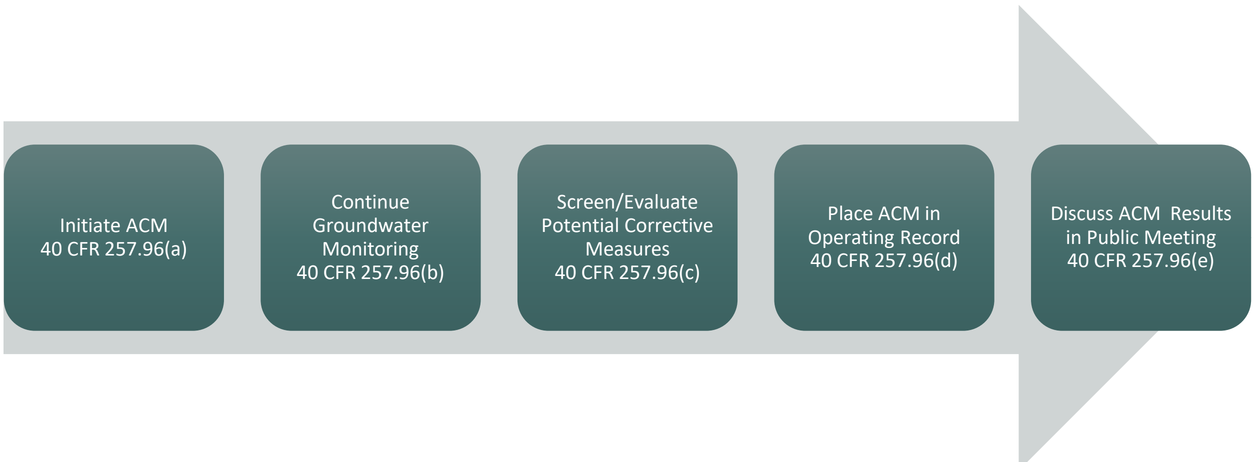
An ACM Report was issued in September 2019 to summarize the remedial alternatives for addressing the Groundwater Protection Standard (GPS) exceedances observed in the October 2018 sampling event, and identified in the Notification of Groundwater Protection Standard Exceedance dated April 15, 2019. The September 2019 ACM identified additional information needed to inform the selection of a corrective measure (remedy) for BGS according to 40 CFR 257.97. Since the ACM was issued, IPL has worked to obtain the needed information and prepared Addendum No. 1 to update the ACM for BGS and discuss additional remedy alternatives.

1.1 ASSESSMENT OF CORRECTIVE MEASURES PROCESS

As discussed above, Addendum No. 1 was prepared to update the ACM Report developed in response to GPS exceedances observed in groundwater samples collected at the BGS facility. The ACM process is one step in a series of steps defined in the CCR Rule and depicted in the graphic below. To date, IPL has implemented a detection monitoring program per 40 CFR 257.94 and completed assessment monitoring at BGS per 40 CFR 257.95. The September 2019 ACM was required based on the groundwater monitoring results obtained through October 2018. With the ACM completed and now updated with new information, IPL is required to select a remedy according to 40 CFR 257.97. The remedy selection process must be completed as soon as feasible and, once selected, IPL is required to start the corrective action process within 90 days.



The process for developing the ACM is defined in 40 CFR 257.96 and is shown in the graphic below. IPL held a public meeting on October 14, 2020, to discuss the September 2019 ACM with interested and affected parties. Additional corrective measure alternatives are identified in Addendum No. 1 that were not discussed at the October 14 meeting. Since IPL is required to discuss the ACM results in a public meeting at least 30 days before selecting a remedy, a second public meeting will be held to discuss the new alternatives. To facilitate the selection of a remedy for the GPS exceedances at BGS, IPL continues to investigate and assess the nature and extent of the groundwater impacts. Information about the site, the groundwater monitoring completed, the groundwater impacts as they are currently understood, and the ongoing assessment activities are discussed in the sections that follow.



1.2 SITE INFORMATION AND MAP

BGS is located along the west bank of the Mississippi River, about 5 miles south of the city of Burlington, in Des Moines County, Iowa (**Figure 1**). The address of the plant is 4282 Sullivan Slough Road, Burlington, Iowa. In addition to the coal-fired generating station, the property also contains a coal stockpile, diesel-fueled combustion turbines, hydrated fly ash storage area, upper ash pond, lower pond, economizer ash pond, bottom ash pond, and ash seal pond.

The groundwater monitoring system at BGS is a multi-unit system. BGS includes four CCR Units:

- BGS Ash Seal Pond (existing CCR surface impoundment)
- BGS Main Ash Pond (existing CCR surface impoundment)
- BGS Economizer Ash Pond (existing CCR surface impoundment)
- BGS Upper Ash Pond (existing CCR surface impoundment)

A map showing the CCR Units and all background (or upgradient) and downgradient monitoring wells with identification numbers for the CCR groundwater monitoring program is provided as **Figure 2**.

2.0 BACKGROUND

2.1 REGIONAL GEOLOGIC INFORMATION

The uppermost geologic formation beneath BGS that meets the definition of the "uppermost aquifer," as defined under 40 CFR 257.53, is the surficial alluvial aquifer. The alluvial aquifer comprises Mississippi River valley clay, silt, sand, and sand and gravel deposits. These deposits are present along the edges of the entire Mississippi River valley in southeastern Iowa. A map of the regional glacial geology in the area is included in **Appendix A.**

The alluvial aquifer is underlain by Devonian-Mississippian limestone bedrock, which is identified as an aquiclude on the regional bedrock geology map of the area included in **Appendix A.**

The regional groundwater flow direction is generally to the east toward the Mississippi River. A map of regional flow is included in **Appendix A.**

2.2 SITE GEOLOGIC INFORMATION

Monitoring wells MW-301 through MW-313, MW-302A, MW-307A, MW-310A, and MW-313A were installed to intersect the alluvial sands at the site. The unconsolidated material at these well locations is generally clay and silt to approximately 61 feet below ground surface (bgs), and these fine-grained sediments are underlain by sand or silty sand. The total boring depths are between 24 and 61 feet bgs. Bedrock was encountered at 35 feet bgs in the boring for upgradient well MW-310A. The thickness of the alluvium at the site is 25 feet in the area of the upgradient wells and at least 61 feet in the area of the downgradient wells. The boring logs for MW-301 through MW-313, MW-302A, MW-307A, MW-310A, and MW-313A are included in **Appendix B.**

Shallow groundwater at the site generally flows to the east and southeast, toward the Mississippi River. The groundwater flow pattern for April 2019 is shown on **Figure 3**. The groundwater elevation data for the CCR monitoring wells are provided in **Table 1**.

A geologic cross section was prepared with background monitoring well nest MW-310/310A and downgradient monitoring wells MW-306 and MW-312. The cross section line runs through the lower southwest section of the BGS Upper Ash Pond, BGS Economizer Ash Pond, and the coal pile. The cross section location is provided on **Figure 2**, and the geologic cross section is provided on **Figure 6**. Unconsolidated geologic material and water table levels estimated using water levels measured at site monitoring wells are identified on the cross section.

2.3 CCR RULE MONITORING SYSTEM

The original groundwater monitoring system established in accordance with the CCR Rule consists of two upgradient (background) monitoring wells and nine downgradient monitoring wells. The two initial background wells are MW-310 and MW-311. The nine initial downgradient wells are MW 301, MW-302, MW-303, MW-304, MW-305, MW-306, MW-307, MW-308, and MW-309. These wells were installed between December 2015 and March 2016. Two additional downgradient monitoring wells, MW-312 and MW-313, were installed in May 2019 and one additional background well, MW-310A, and three additional downgradient wells, MW-302A, MW-307A, and MW-313A, were installed in June and July of 2020 in accordance with the assessment monitoring requirements of 40 CFR 257.95(g)(1). The majority of the CCR Rule wells are installed in the alluvial aquifer. One deeper background well, MW-310A, is installed in the bedrock aquifer that is hydraulically connected to the alluvial aquifer. Well depths range from approximately 19 to 61 feet bgs. The Groundwater Sampling and Analysis Plan was followed for the sampling and analysis of all existing and new wells.

3.0 NATURE AND EXTENT OF GROUNDWATER IMPACTS

3.1 POTENTIAL SOURCES

The potential sources of groundwater impacts are currently under evaluation. Based on the March 2018 History of Construction for BGS, prepared in accordance with §257.73(c) of the CCR Rule, potential sources of groundwater impacts from the monitored CCR units include the following:

CCR Unit	Potential Sources	Description	Quantity
Ash Seal Pond	CCR	Bottom ash, economizer ash, and precipitator ash	108,800 C.Y.
	Low volume waste water from generating plant	Legacy operations	Regular flows ceased in 2009; may be used during maintenance operations
	Storm water	Annual precipitation	25.0 acre-feet (AC-FT) (Watershed of 7.7 acres)
Main Ash Pond	CCR	Bottom ash, economizer ash, precipitator fly ash, and hydrated fly ash	487,100 C.Y.
	Low volume waste water from generating plant	Boiler seal water system, rinse water from previous chemical cleans, waste water from non-chemical metal cleaning (air heater wash and economizer wash), and boiler makeup/ blowdown water	Average flow is approximately 0.63 million gallons per day (MGD)
	Storm water	Annual precipitation	60.8 AC-FT (Watershed of 18.7 acres)
Economizer Ash Pond	CCR	Economizer ash and precipitator fly ash	535,400 C.Y.
	Storm water	Annual precipitation	35.8 AC-FT (Watershed of 11 acres)
Upper Ash Pond	CCR	Bottom ash, economizer ash, and precipitator fly ash	187,800 C.Y.
	Low volume waste water flows from generating plant	Bottom ash sluicing activities, economizer ash sluicing activities, and process water flows from the generating plant	Average flow from April 2018 – April 2019 was 3.06 MGD
	Storm water	Annual precipitation	43.2 AC-FT (Watershed of 13.3 acres)

Notes: Storm water volume is calculated based on the watershed area for the pond and the annual average precipitation for Burlington, Iowa, of 39 inches/year. The average flow from the Main Ash Pond is based on 36 months of flow data for Outfall 006 over the period of 2006 through 2009. The calculation for average flow from the Upper Ash Pond excludes days when back waters affected flow measurements at Outfall 001.

Estimated CCR quantities have been updated using data from soil borings installed in and around the CCR surface impoundments in December 2019 and January 2020.

Groundwater elevations at BGS have fluctuated by as much 12 feet over the groundwater monitoring that started in 2016. Groundwater elevation data provided in **Table 1** and information available in the operating record for the CCR surface impoundments at BGS, including the March 2018 History of Construction report (HHS 2018) and periodic inspection reports such as the July 2020 CCR Surface Impoundment Annual Inspection Report (HHS 2020), show that some portion of the CCR in the impoundments is likely to be in contact with groundwater at times. The volume of CCR in contact with groundwater will need to be considered as the remedy selection process is completed.

3.2 GROUNDWATER ASSESSMENT

3.2.1 Groundwater Depth and Flow Direction

Depth to groundwater as measured in the site monitoring wells varies from 1 to 17 feet bgs due to topographic variations across the facility and seasonal variations in water levels. Groundwater flow at the site is generally to the east-southeast, and the groundwater flow direction and water levels fluctuate seasonally due to the proximity to the river. Groundwater elevations and flow directions are shown on the April 2019, June 2020, and September 2020 potentiometric surface maps (**Figures 4, 5,** and **6**).

3.2.2 Groundwater Protection Standard Exceedances Identified

The ACM process was triggered by the detection of lithium and molybdenum at statistically significant levels exceeding the GPSs in samples from the following compliance wells:

- Lithium: MW-302, MW-307, MW-308
- Molybdenum: MW-302, MW-307, MW-308

This statistical evaluation of the assessment monitoring results was based on the first four sampling events for the Appendix IV assessment monitoring parameters, including complete sampling events in May, August, and October 2018, and a resampling event for selected wells in March 2019. The complete results for these sampling events are summarized in **Table 3**. Some additional compliance monitoring wells had individual results exceeding the GPSs for these parameters, but the exceedances were not determined to be at statistically significant levels. The evaluation of statistically significant levels exceeding the GPSs was summarized in an Alternative Source Demonstration (ASD) completed in April 2019. This ASD identified a reduced list of well-parameters exceeding the GPS and recommended that IPL initiate the ACM.

In the subsequent April 2019, October 2019, June 2020, and October 2020 sampling events, additional wells with statistically significant levels exceeding the GPSs for lithium and/or molybdenum were identified through additional data collection at existing wells or installation and sampling on new wells. No additional parameters were detected at concentrations exceeding GPSs. Statistically significant levels above the GPS have been identified for the following wells and parameters:

Assessment Monitoring Appendix IV Parameters	Location of GPS Exceedance(s)	Historic Range of Detections at Wells With SSL Above GPS	Groundwater Protection Standards (GPS)
Lithium (µg/L)	MW-302, MW-303, MW-304, MW-306, MW-307, MW-308, MW-313	34.3 – 92	40
Molybdenum (µg/L)	MW-302, MW-307, MW-308, MW-312, MW-313	100 - 320	100

µg/L = micrograms per liter, SSL = Statistically significant level
Note: Historic range includes results from assessment monitoring beginning in April 2018 through October 2020.

3.2.3 Expanding the Groundwater Monitoring Network

Monitoring wells MW-312 and MW-313 were installed in May 2019 downgradient of the CCR units and near the Mississippi River. Monitoring wells MW-312 and MW-313 were installed to expand the groundwater monitoring network at BGS beyond the edge of the CCR unit boundaries and to fulfill the requirements of 40 CFR 257.95(g)(1), which requires additional characterization to support a complete and accurate assessment of corrective measures. Groundwater samples were collected following installation of the two new monitoring wells.

Downgradient monitoring wells MW-302A, MW-307A, and MW-313A and upgradient well MW-310A were installed in June and July 2020. They were installed as deeper nested wells with an existing piezometer to an approximate depth of 60 feet bgs to vertically expand the monitoring network at BGS.

The sampling results from MW-312 and MW-313, shown in **Table 3**, indicate that lithium exceeded the GPS in four samples from MW-313 and molybdenum exceeded the GPS in four samples from both wells. The initial two rounds of sampling results from MW-302A, MW-307A, MW-310A and MW-313A, shown in **Table 3**, indicate that lithium concentrations are below the GPS in all of the samples from the four deeper piezometers. Molybdenum concentrations were greater than the GPS in samples in both rounds from the deeper downgradient piezometers MW-302A, MW-307A, and MW-313A, but not in the deeper upgradient piezometer MW-310A.

The statistical significance of the GPS exceedances for these new wells will be assessed and the potential role of alternative sources will be evaluated once additional sampling has been completed.

3.2.4 MNA Data Collection and Evaluation

An evaluation of the potential for BGS to utilize MNA as a corrective action alternative began with the initiation of an ACM at BGS. The tiered analysis approach in the USEPA guidance, "Monitored Natural Attenuation of Inorganic Contaminants in Groundwater, Volume 1 – Technical Basis for Assessment" (USEPA, 2007), is being used as a guide for evaluating MNA as a potential corrective action alternative at BGS.

There are four tiers of analysis to be addressed in evaluating the site for MNA:

1. Demonstrate active contaminant removal from groundwater
2. Determine mechanism and rate of attenuation

3. Determine system capacity and stability of attenuation
4. Design a performance monitoring program and identify an alternative remedy

Data collection activities during the assessment monitoring and ACM process that begins to address the objectives of tiers 1 and 2 include:

- Installation of downgradient assessment wells MW-312 and MW-313 and deeper upgradient and downgradient piezometers MW-302A, MW-307A, MW-310A, and MW313A to evaluate groundwater flow direction and horizontal and vertical hydraulic gradients.

- Additional groundwater sampling events and analysis of data from all site wells to evaluate contaminant distribution in groundwater and stability of groundwater concentrations over time.

- Analysis of general groundwater chemistry and field parameters in addition to the Appendix III and IV constituents to provide further characterization of groundwater chemistry.

- Analysis of both total and dissolved constituents for selected parameters.

A hydrogeochemical conceptual model and summary of preliminary evaluation of groundwater contaminant attenuation at BGS is included in **Appendix C.** Preliminary findings include:

- Lithium and molybdenum have likely been released from one or more sources (ponds) to the confined alluvial aquifer beneath the site.

- Molybdenum concentrations are comparable in the shallow and deeper portions of the aquifer, indicating that downward vertical gradients within the aquifer have carried molybdenum to depths of at least 60 feet bgs.

- Lithium concentrations decrease significantly with depth, suggesting that some form of attenuation may be present in the upper portions of the aquifer.

- Masses of 27 and 81 kilograms of lithium and molybdenum, respectively, are estimated to be dissolved in groundwater beneath the BGS site.

- The proximity of the Mississippi River, immediately adjacent to BGS, limits, but does not necessarily preclude, the potential for natural attenuation within the aquifer.

- Geochemical data collected to date does not support the presence of natural attenuation for lithium or molybdenum.

- The lithium and molybdenum GPS exceedances in the deep piezometers cannot be confirmed to be statistically significant until a minimum of two additional rounds of samples are collected.

A preliminary evaluation of whether the lithium and molybdenum plume is stable, growing, or decreasing has been completed using a Mann-Kendall trend test. The results of the trend test are provided in **Appendix D.** No statistically significant increasing or decreasing trends were identified in the results obtained since assessment monitoring was initiated. Additional groundwater sampling rounds that include the deep piezometers are required before a complete evaluation is possible.

Before natural attenuation is removed from consideration as a remedial alternative, the following additional data collection and evaluation is recommended:

- Perform additional rounds of groundwater sampling for lithium and molybdenum to further assess plume stability.
- Perform laboratory analysis on aquifer soil samples from areas where lithium concentrations are low or not detected to evaluate lithium adsorption capacity.
- Perform additional research on any published lithium and molybdenum groundwater concentration data from the alluvial aquifer in the vicinity of BGS.

3.3 CONCEPTUAL SITE MODEL

The following conceptual site model describes the compounds and nature of constitutes above the GPS, discusses potential exposure pathways affecting human health and the environment, and presents a cursory review of their potential impacts. The conceptual site model for BGS has been prepared in general conformance with the Standard Guide for Developing Conceptual Site Models for Contaminated Sites (ASTM E1689-95). This conceptual site model is the basis for assessing the efficacy of likely corrective measures to address the source, release mechanisms, and exposure routes.

3.3.1 Nature of Constituents Above GPS

The nature of the constituents in groundwater at BGS that are present at concentrations greater than the GPS (lithium and molybdenum) were described in the September 2019 ACM. No additional constituents have been identified at concentrations above a GPS. Please refer to the details discussion previously provided in Section 3.3.1 of the 2019 ACM.

3.3.2 Potential Receptors and Pathways

As described in **Section 3.3**, ASTM E1689-95 provides a framework for identifying potential receptors (people or other organisms potentially affected by the groundwater impacts at BGS) and pathways (the ways groundwater impacts might reach receptors). In accordance with ASTM E1689-95, we have considered both potential human and ecological exposures to groundwater impacted by the constituents identified in **Section 3.2.3**:

Human Health
In general, human health exposure routes to contaminants in the environment include ingestion, inhalation, and dermal contact with the following environmental media:

- Groundwater
- Surface Water and Sediments
- Air
- Soil
- Biota/Food

If people might be exposed to the impacts described in **Section 3.0** via one of the environmental media listed above, a potential exposure route exists and is evaluated further. For the groundwater impacts at BGS, the following potential exposure pathways have been identified with respect to human health:

- Groundwater – Ingestion and Dermal Contact: The potential for ingestion of, or dermal contact with, impacted groundwater from BGS exists if water supply wells are present in the area of impacted groundwater and are used as a potable water supply. Based on a review of the Iowa Department of Natural Resources (IDNR) GeoSam well database and information provided by BGS:
  - No water supply wells have been identified downgradient or sidegradient in the vicinity of the CCR units.
  - The on-site water supply well is not used as a source of potable water. Potable water at BGS is provided by the Rathbun Regional Water Association.

- Surface Water and Sediments – Ingestion and Dermal Contact: The potential for ingestion of or dermal contact with impacted surface water and sediments exists if impacted groundwater from the BGS facility has interacted with adjacent surface water and sediments, to the extent that the constituents identified in **Section 3.2.3** are present in these media at concentrations that represents a risk to human health.

- Biota/Food – Ingestion: The potential for ingestion of impacted food exists if impacted groundwater from the BGS facility has interacted with elements of the human food chain. Based on discussions with BGS facility staff, no hunting or farming occurs within the current area of known groundwater impacts. Elements of the food chain may also be exposed indirectly through groundwater-to-surface water interactions, which are subject to additional assessment.

Based on the lack of groundwater exposure, only the surface water, sediment, and biota/food exposure pathways were retained for further consideration in the September 2019 ACM. However, the implementation of potential corrective measures may introduce secondary exposure pathways that are discussed in **Section 6.0** and will be evaluated further as a corrective measure is selected for BGS.

Ecological Health

In addition to human exposures to impacted groundwater, potential ecological exposures are also considered. If ecological receptors might be exposed to impacted groundwater, the potential exposure routes are evaluated further. Ecological receptors include living organisms, other than humans, the habitat supporting those organisms, or natural resources potentially adversely affected by CCR impacts. This includes:

- Transfer from an environmental media to animal and plant life. This can occur by bioaccumulation, bioconcentration, and biomagnification:
  - Bioaccumulation is the general term describing a process by which chemicals are taken up by a plant or animal either directly from exposure to impacted media (soil, sediment, water) or by eating food containing the chemical.

  - Bioconcentration is a process in which chemicals are absorbed by an animal or plant to levels higher than the surrounding environment.

  - Biomagnification is a process in which chemical levels in plants or animals increase from transfer through the food web (e.g., predators have greater concentrations of a particular chemical than their prey).

- Benthic invertebrates within adjacent waters.

Based on the information available and presented in the September 2019 ACM, both of the ecological exposure routes required additional evaluation at the time.

Since the September 2019 ACM was completed, exposure pathways subject to groundwater to surface water interactions have been evaluated further through the following:

- Review of USEPA and state surface water standards for lithium and molybdenum.
- Literature review for toxicity of lithium and molybdenum.
- Review of application materials and studies conducted by IPL for the renewal of the National Pollutant Discharge Elimination System (NPDES) permit for BGS.

Based on our evaluation to date, the molybdenum and lithium impacts to groundwater at BGS are unlikely to impact the river. This preliminary conclusion is based on the following:

- Neither USEPA nor the State of Iowa have established surface water standards for these metals. Surface water standards identified in our review are higher than the GPS for these metals and generally higher than the concentrations observed in groundwater at BGS (see standards established in New Mexico, Nevada, and California).

- Neither metal is highly toxic to aquatic organisms, and toxicity testing for these metals found in literature identify "Effective Concentrations" and "No Observable Effect Concentrations" that are higher than the GPS and concentrations observed in groundwater at BGS.

- No population shifts in the mussel communities upstream and downstream of BGS in the Mississippi River were observed in mussel surveys completed to support the NPDES Permit renewal for BGS (Alliant 2019). Mussels, one of the most sensitive animal groups, present at the likely point of groundwater to surface water interaction, showed no population shifts that would be indicative of chronic or acute impacts.

Although an initial assessment indicates that molybdenum and lithium in groundwater at BGS is unlikely to impact the Mississippi River or people and biota utilizing the river, the groundwater-to-surface-water interactions at BGS are the subject of ongoing assessment.

The surface water/sediment, biota/food, and ecological exposure assessment is incomplete as the concentrations within surface water and sediment are presently unknown. The concentrations within groundwater are likely higher and not representative of the surface water subject to dermal contact and ingestion. Similarly, the concentrations within groundwater are likely higher than those interfacing the ecological receptors. Evaluation of constituent concentrations in sediment and surface water may be estimated through calculations and/or additional sampling.

4.0 POTENTIAL CORRECTIVE MEASURES

In this section, we identify potential corrective measures to meet the ACM goals identified in 40 CFR 257.96(a), which are to:

- Prevent further releases
- Remediate releases
- Restore affected areas to original conditions

The development of corrective measure alternatives is described further in the following sections. Corrective measure alternatives developed to address the groundwater impacts at BGS are described in **Section 5.0**. The alternatives selected are qualitatively evaluated in **Section 6.0**.

4.1 IDENTIFICATION OF CORRECTIVE MEASURES

As described in the USEPA Solid Waste Disposal Facility Criteria Technical Manual (USEPA, 1998), corrective measures generally include up to three components, including:

- Source Control
- Containment
- Restoration

Within each component, there are alternative measures that may be used to accomplish the component objectives. The measures from one or more components are then combined to form corrective measure alternatives (discussed in **Section 5.0**) intended to address the observed groundwater impacts. Potential corrective measures were identified based on site information available during development of the ACM for the purpose of meeting the goals described in **Section 4.0**.

Each component and associated corrective measures are further identified in subsequent paragraphs. The corrective measures are evaluated for feasibility and combined to create the corrective action alternatives identified in this section, and further evaluated in **Section 5.0**. We continue to evaluate site conditions and may identify additional corrective measures based on new information regarding the nature and extent of the impacts.

4.1.1 Source Control

The source control component of a corrective measure is intended to identify and locate the source of impacts and provide a mechanism to prevent further releases from the source. For the BGS site, the sources to be controlled are the CCR materials in the impoundments and the associated process water. Each of the source control measures below require closure of the impoundments and for waste water to be re-directed from the CCR units to eliminate the flows that may mobilize constituents from the CCR and transport them to groundwater. We have identified the following potential source control measures:

- **Close and cap in place.** Close the CCR surface impoundments and cap the CCR in the four impoundments in place to reduce the infiltration of rain water into the impoundments, and prevent transport of CCR constituents from unsaturated CCR materials into the groundwater, and reduce the potential for CCR to interface with groundwater.

- **Consolidate and cap.** Consolidate CCR from the four CCR surface impoundments into one or two areas to reduce the cap area exposed to infiltration, reduce the potential source footprint, prevent transport of CCR constituents from unsaturated CCR materials into the groundwater, and minimize the potential for CCR to interface with groundwater.

- **Consolidate and cap with chemical stabilization.** Consolidate CCR from the four CCR surface impoundments into one or two areas to reduce the cap area exposed to infiltration, reduce the potential source footprint, prevent transport of CCR constituents from unsaturated CCR materials into the groundwater, and minimize the potential for CCR to interface with groundwater. Mix a chemical amendment into CCR in-situ prior to placing additional CCR for consolidation and mix the amendment into CCR as it is excavated and placed for consolidation to reduce the mobility of select CCR constituents in the environment. Chemical stabilization may include the use of one or multiple admixtures that serve to physically and/or chemically stabilize the constituents of concern within the CCR. Physically, this may include solidification with cementitious or polymeric materials. Chemically, this may include precipitation or alteration to render arsenic less mobile in the environment. Evaluation of an appropriate commodity amendment that may include Calcium Polysifide, Portland Cement, Calcium Oxide, and/or proprietary chemicals such as FerroBlack-H, MAECTITE, 3Dme, and/or MRC, will occur during the remedy selection process.

- **Excavate and create on-site disposal area.** Excavate and place CCR in a newly lined landfill area on site to prevent further releases from the four potential source areas and isolate the CCR from potential groundwater interactions. Cap the new landfill with final cover to prevent the transport of CCR constituents from unsaturated CCR.

- **Excavate and dispose at a licensed off-site disposal area.** Remove all CCR from the site and haul to a licensed landfill to prevent further on-site releases from the CCR areas.

Water movement through the CCR materials is the mechanism for CCR impacts to groundwater, including surface water that moves vertically through the CCR materials via infiltration of precipitation and surface water runoff.

Based on the available information for this site, all the source control measures have potential to prevent further releases caused by infiltration, thus are retained for incorporation into alternatives for further evaluation.

Based on the ongoing evaluation of MNA mechanisms and site attenuation capacity, chemical stabilization has been added as a source control alternative. Additional source control may be needed to address CCR that could be in contact with groundwater after closure in place if MNA mechanisms are not active at BGS or the site does not have the attenuation capacity to reduce groundwater concentrations of molybdenum and lithium below the GPS.

4.1.2 Containment

The objective of containment is to limit the spread of the impacts beyond the source. The need for containment depends on the nature and extent of impacts, exposure pathways, and risks to receptors. Containment may also be implemented in combination with restoration as described in **Section 4.1.3**.

Containment may be a recommended element of a corrective measure if needed to:

- Prevent off-site migration of groundwater impacts
- Cease completion of a confirmed exposure pathway (e.g., water supply well)

Containment may also be used in lieu of active restoration if an active approach is needed; however, containment with active treatment is not warranted when:

- Water in the affected aquifer is naturally unsuited for human consumption.
- Contaminants are present in low concentration with low mobility.
- Low potential for exposure pathways to be completed, and low risk associated with exposure.
- Low transmissivity and low future user demand.

The following containment measures have potential to limit the spread of continued or remaining groundwater impacts at this site, if necessary:

- **Gradient Control with Pumping.** Gradient control includes a measure to alter the groundwater velocity and direction to slow or isolate impacts. This can be accomplished with pumping wells and/or a trench/sump collection system. If groundwater pumping is considered for capturing an impacted groundwater plume, the impacted groundwater must be managed in conformance with all applicable federal and state requirements.

- **Gradient Control with Phytotechnology.** Gradient control with phytotechnology relies on the ability of vegetation to evapotranspire sources of surface water and groundwater. Water interception capacity by the aboveground canopy and subsequent evapotranspiration through the root system can limit vertical migration of water from the surface downward. The horizontal migration of groundwater can be controlled or contained using deep-rooted species, such as prairie plants and trees, to intercept, take up, and transpire the water. Trees classified as phreatophytes are deep-rooted, high-transpiring, water-loving organisms that send their roots into regions of high moisture and can survive in conditions of temporary saturation.

- **Chemical Stabilization.** Stabilization refers to processes that involve chemical reactions that reduce the leachability of lithium and molybdenum. Stabilization chemically immobilizes impacts or reduces their solubility through a chemical reaction. The desired results of stabilization methods include converting metals into a less soluble, mobile, or toxic form.

- **Containment Walls.** Containment walls can be applied in two ways; first, a wall that creates a physical barrier to the flow of groundwater to limit the movement of constituents of concern in groundwater, and second, a passive barrier installed to intercept the flow of groundwater and constructed with a reactive media designed to adsorb, precipitate, or degrade groundwater constituents to limit their movement in the environment (FRTR 2020).

Based on the currently available information for this site, an active MNA mechanism is yet to be identified, and the assessment of the site capacity to attenuate the lithium and molybdenum impacts to groundwater is ongoing. Thus, active containment may be required for this site due to the potential for CCR to remain in contact with groundwater following closure in place.

4.1.3 Restoration

Restoration is the process through which groundwater quality is restored to meet GPSs. This can be accomplished by way of MNA or intensively addressed by groundwater treatment with or without extraction.

MNA can be a viable remedy or component of a remedial alternative for groundwater impacted with metals. MNA requires ongoing involvement and potentially intense characterization of the geochemical environment to understand the attenuation processes involved, and to justify reliance on them and regular, long-term monitoring to ensure the attenuation processes are meeting remedial goals.

MNA is not a “do-nothing” alternative; rather, it is an effective knowledge-based remedy where a thorough engineering analysis provides the basis for understanding, monitoring, predicting, and documenting natural processes. To properly employ this remedy, there needs to be a strong scientific basis supported by appropriate research and site-specific monitoring implemented in accordance with quality controls. The compelling evidence needed to support proper evaluation of the remedy requires that the processes that lower metal concentrations in groundwater be well understood.

If active treatment is implemented, water may be treated in-situ, on-site, or off-site. The need for active treatment depends on the nature and extent of impacts, exposure pathways, and risks to receptors. If there are no receptors, or when active treatment is not required for the reasons discussed in Section 4.1.2, then MNA is an appropriate option. If existing or future impacts require a more rapid restoration of groundwater quality, then active restoration may be needed.

Treated groundwater may be re-injected, sent to a local publicly owned treatment works (POTW), or discharged to a local body of surface water, depending on local, state, and federal requirements. Typical on-site treatment practices for metals include coagulation and precipitation, ion exchange, or reverse osmosis. Off-site wastewater treatment may include sending the impacted groundwater that is extracted to a local POTW or to a facility designed to treat the contaminants of concern.

The removal rate of groundwater constituents such as lithium and molybdenum will depend on the rate of groundwater extraction, the cation exchange capacity of the soil, and partition coefficients of the constituents sorbed to the soil. As the concentration of metals in groundwater is reduced, the rate at which constituents become partitioned from the soil to the aqueous phase may also be reduced. The amount of flushing of the aquifer material required to remove the metals and reduce their concentration in groundwater below the GPS will generally determine the time frame required for restoration. This time frame is site-specific.

In-situ methods may be appropriate, particularly where pump and treat technologies may present adverse effects. In-situ methods may include the introduction of a chemical amendment to adsorb, precipitate, or degrade a contaminant or biological restoration requiring pH control, addition of specific micro-organisms, and/or addition of nutrients and substrate to augment and encourage degradation by indigenous microbial populations. Bioremediation requires laboratory treatability studies and pilot field studies to determine the feasibility and the reliability of full-scale treatment.

Based on current available information, MNA mechanisms at BGS are still being evaluated, along with the capacity of the site to attenuate the molybdenum and lithium impacts to groundwater. Other restoration measures have been included in this addendum to increase the breadth of alternatives evaluated and available for consideration during the remedy selection process. These additional alternatives are discussed in **Section 5.0**.

5.0 CORRECTIVE MEASURE ALTERNATIVES

We have preliminarily identified the following corrective measure alternatives for the groundwater impacts at BGS:

- Alternative 1 – No Action
- Alternative 2 – Close and Cap in Place with MNA
- Alternative 3 – Consolidate and Cap with MNA
- Alternative 4 – Excavate and Dispose On Site with MNA
- Alternative 5 – Excavate and Dispose in Off-site Landfill with MNA
- Alternative 6 – Consolidate and Cap with Chemical Amendment
- Alternative 7 – Consolidate and Cap with Groundwater Collection
- Alternative 8 – Consolidate and Cap with Barrier Wall

These alternatives were developed by selecting components from the reasonable and appropriate corrective measures components discussed above. With the exception of the No Action alternative, each of the corrective measure alternatives meet the requirements in 40 CFR 257.97(b)(1) through (5) based on the information available at the current time. We may identify additional alternatives based on the continued evaluation of site conditions.

5.1 ALTERNATIVE 1 – NO ACTION

IPL is committed to implementing corrective measures as required under the Rule, and the No-Action alternative is only included as a baseline condition and a point of comparison for the other alternatives. The consideration of this alternative assumes the monitoring of groundwater continues under this action.

5.2 ALTERNATIVE 2 – CLOSE AND CAP IN PLACE WITH MNA

Alternative 2 includes closing the impoundments (no further discharge), covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d). This measure is consistent with landfill cover systems to prevent infiltration of surface water into the CCR as described in **Section 4.1.1**. The capped areas will be subject to enhanced groundwater monitoring via MNA.

This alternative eliminates CCR sluicing/plant process water discharges and, with the installation of a cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. Further leaching of metals and migration within groundwater will be reduced and may be eliminated over time. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

5.3 ALTERNATIVE 3 – CONSOLIDATE ON-SITE AND CAP WITH MNA

Alternative 3 includes closing the impoundments (no further discharge), relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d). This measure is consistent with landfill cover systems to prevent infiltration of surface water into the CCR as described in Section 4.1.1. The consolidated and capped areas will be subject to enhanced groundwater monitoring via MNA.

This alternative eliminates CCR sluicing/plant process water discharges and, with the consolidation of the CCR footprint and the installation of a cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. Consolidation of CCR into a smaller footprint during closure also reduces the volume of potential source materials that may be in contact with groundwater after closure. Further leaching of metals and migration within groundwater will be reduced and may be eliminated over time. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

5.4 ALTERNATIVE 4 – EXCAVATE AND DISPOSE ON-SITE WITH MNA

Alternative 4 includes closing the impoundments (no further discharge), excavation of CCR from the source area, and creation of a new on-site disposal area with a liner and cap system. This alternative will serve to contain the CCR at the site and allow for the collection and management of liquids generated from the disposal area. Further releases from the current source will be prevented by the use of engineering controls constructed/installed to meet the design criteria for new CCR landfills required under 40 CFR 257.70.

This alternative eliminates CCR sluicing/plant process water discharges and, with the consolidation of the CCR footprint and the installation of a new on-site disposal area liner and cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

5.5 ALTERNATIVE 5 – EXCAVATE AND DISPOSE IN OFF-SITE LANDFILL WITH MNA

Alternative 5 includes closing the impoundments (no further discharge), excavation of all CCR, and transport to an approved off-site landfill. Further on-site releases from the CCR sources will be prevented by relocating the source material to another site, which eliminates the potential for ongoing leaching of constituents into groundwater at BGS.

This alternative eliminates CCR sluicing/plant process water discharges and, with the removal of CCR from the site, will eliminate infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/ surface water infiltration. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

5.6 ALTERNATIVE 6 – CONSOLIDATE AND CAP WITH CHEMICAL AMENDMENT

Alternative 6 includes closing the impoundments (no further discharge), adding a chemical amendment to in-place CCR and relocated CCR to reduce the mobilization of molybdenum and lithium prior to relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d). This measure is consistent with landfill cover systems to prevent infiltration of surface water into the CCR and the reduced contaminant mobilization achieved by chemical amendment as described in **Section 4.1.1**.

This alternative eliminates CCR sluicing/plant process water discharges and, with the consolidation of the CCR footprint and the installation of a cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. Consolidation of CCR into a smaller footprint during closure also reduces the volume of potential source materials that may be in contact with groundwater after closure. Further leaching of metals and migration within groundwater will be reduced by minimizing the footprint of CCR in contact with groundwater and by fixation using a chemical amendment.

5.7 ALTERNATIVE 7 – CONSOLIDATE AND CAP WITH GROUNDWATER COLLECTION

Alternative 7 includes closing the impoundments (no further discharge), relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d). This measure is consistent with landfill cover systems to prevent infiltration of surface water into the CCR as described in **Section 4.1.1**. Impacted groundwater will be collected using pumps and treated prior to discharge according to state and federal requirements as described in **Section 4.1.2**.

This alternative eliminates CCR sluicing/plant process water discharges and, with the consolidation of the CCR footprint and the installation of a cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. Consolidation of CCR into a smaller footprint during closure also reduces the volume of potential source materials that may be in contact with groundwater after closure. Further leaching of metals and migration within groundwater will be reduced and may be eliminated over time as impacted groundwater is collected to contain and restore molybdenum and lithium concentrations in groundwater to levels below the GPS.

5.8 ALTERNATIVE 8 – CONSOLIDATE AND CAP WITH BARRIER WALL

Alternative 8 includes closing the impoundments (no further discharge), relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d). This measure is consistent with landfill cover systems to prevent infiltration of surface water into the CCR as described in **Section 4.1.1**. Impacted groundwater will be intercepted with a barrier wall to minimize the migration of molybdenum and lithium as described in **Section 4.1.2**.

This alternative eliminates CCR sluicing/plant process water discharges and, with the consolidation of the CCR footprint and the installation of a cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. Consolidation of CCR into a smaller footprint during closure also reduces the volume of potential source materials that may be in contact with groundwater after closure. Further leaching of metals and migration within groundwater will be reduced and may be eliminated over time as impacted groundwater is intercepted with a barrier wall to minimize the spread of molybdenum and lithium in groundwater.

6.0 EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

As required by 40 CFR 257.96(c), the following sections provide an evaluation of the effectiveness of corrective measure alternatives in meeting the requirements and objectives outlined in 40 CFR 257.97. The evaluation addresses the requirements and objectives identified in 40 CFR 257.96(c)(1) through (3), which include:

- The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to residual contamination.
- The time required to begin and complete the remedy.
- The institutional requirements, such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy.

In addition to the discussion of the items listed above, **Table 4** provides a summary of the initial evaluation of the alternatives including each of the criteria listed in 40 CFR 257.97.

6.1 ALTERNATIVE 1 – NO ACTION

As described in **Section 5.1**, the No Action alternative is only included as a baseline condition and a point of comparison for the other alternatives. This alternative does not satisfy all five criteria in 40 CFR 257.97(b)(1) through (5), so it is not an acceptable corrective measure under the CCR Rule. For comparison only, Alternative 1 is evaluated with regard to the criteria in 40 FR 257.96(c) below:

- **Performance, Reliability, Implementation, and Impacts.**
  - **Performance.** The ability to attain the GPS for lithium and molybdenum without any additional action is unlikely.
  - **Reliability.** Alternative 1 does not provide any reduction in existing risk.
  - **Implementation.** Nothing is required to implement Alternative 1.
  - **Impacts.** No additional safety or cross-media impacts are expected with Alternative 1. This alternative does not control current suspected routes of exposure to residual contamination.
- **Timing.** No time is required to begin; however, the time required to attain the GPS for lithium and molybdenum under Alternative 1 is unknown.

- **Institutional Requirements.** No institutional requirements beyond maintaining current regulatory approvals exist for Alternative 1.

6.2 ALTERNATIVE 2 – CLOSE AND CAP IN PLACE WITH MNA

As described in **Section 5.2**, Alternative 2 includes closing the impoundments, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d).

- **Performance, Reliability, Implementation, and Impacts.**
  - **Performance.** Ceasing wastewater discharges and closing the impoundments by capping is expected to address infiltration, which is a key contributor to groundwater impacts. MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 2 is capable of and expected to attain the GPS for lithium and molybdenum.

  - **Reliability.** The expected reliability of capping is good. Capping is a common practice and standard remedial method for closure in place in remediation and solid waste management. There is significant industry experience with the design and construction of this method.

  - **Implementation.** The complexity of constructing the cap is low. Dewatering will be required to the extent a suitable subgrade is established for cap construction, which can likely be achieved through standard dewatering methods. The cap construction may put a high demand on the local supply of suitable cap materials. The local availability of cap materials will be evaluated further during remedy selection. The equipment and personnel required to implement Alternative 2 are not specialized and are generally readily available.

  - **Impacts.** Safety impacts associated with the implementation of Alternative 2 are not significantly different than other heavy civil construction projects. Cross-media impacts are expected to be limited due to the small volume of CCR expected to be relocated on site, the short duration of cap construction, the effectiveness of standard engineering controls during construction (e.g., dust control), and the lack of off-site transportation of CCR. Although the risk to surface water receptors is already low, and ending wastewater discharges and capping the impoundments minimizes infiltration (a significant source of water and CCR interaction), some interaction between CCR and groundwater will remain. The ease of implementation and the low-impact nature of MNA as a groundwater restoration method must be evaluated against the effectiveness of passive groundwater restoration, which is the subject of ongoing evaluations. A lack of active MNA mechanism, insufficient site attenuation capacity, or changes in groundwater conditions may require additional action to restore groundwater or prevent cross-media impacts between groundwater and surface water. The potential for exposure to residual contamination is low since CCR will be capped.

- **Timing.** Closure of the impoundments can be completed within 1-2 years following cessation of ash placement in the impoundments. Coal will no longer be used as a fuel at BGS after December 31, 2021, and the closure of the impoundments is expected to be complete by October 17, 2023. The time required to attain the GPS for lithium and molybdenum will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. Alternative 2 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 2:
  - IDNR Closure Permit
  - Federal, state, and local floodplain permits
  - State and local erosion control/construction storm water management permits
  - Federal and state wetland permitting may also be required.

6.3 ALTERNATIVE 3 – CONSOLIDATE ON-SITE AND CAP WITH MNA

As described in **Section 5.3**, Alternative 3 includes closing the impoundments, relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d).

- **Performance, Reliability, Implementation, and Impacts.**
  - **Performance.** Ceasing wastewater discharges and closing the impoundments by capping is expected to address infiltration, which is a key contributor to groundwater impacts. The consolidation of CCR into a smaller footprint may enhance the performance of the cap by further reducing the area exposed to limited post-construction infiltration through the cap. The smaller closure footprint also reduces the potential for ongoing CCR contact with groundwater. MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 3 is capable of and expected to attain the GPS for lithium and molybdenum.

  - **Reliability.** The expected reliability of capping is good. Capping is a common practice and standard remedial method for closure in place in remediation and solid waste management. There is significant industry experience with the design and construction of this method. A consolidated cap footprint may enhance reliability by reducing the scale of post-closure maintenance.

  - **Implementation.** The complexity of constructing the cap is low. The logistics of moving CCR around the site to consolidate the closure footprint increases the complexity of the alternative. CCR dewatering will be required to the extent required to excavate and relocate CCR within the CCR impoundments and provide a suitable subgrade for cap construction. Some conditioning (e.g., drying) of relocated CCR is expected during on-site re-disposal. Alternative 3 can likely be achieved through standard dewatering and conditioning methods. Although the cap footprint will be minimized, cap construction may put a high demand on the local supply of suitable cap materials. The local availability of cap materials will be evaluated further during remedy selection. The equipment and personnel required to implement Alternative 3 are not specialized and are generally readily available.

  - **Impacts.** Safety impacts associated with the implementation of Alternative 3 are not significantly different than other heavy civil construction projects. The level of disturbance required to consolidate CCR before capping may represent some increase in safety risk due to site conditions and on-site construction traffic. Cross-media impacts are expected to be limited due to the small volume of CCR expected to be relocated on site, the short duration of cap construction, the effectiveness of standard engineering controls during construction (e.g., dust control), and the lack of off-site transportation of CCR. Although the risk to surface water receptors is already low and ending wastewater discharges and capping the impoundments minimizes infiltration (a significant source of water and CCR interaction), some interaction between CCR and groundwater will remain. The consolidation of CCR prior to capping under Alternative 3 reduces the potential for CCR and groundwater interaction after closure. The ease of implementation and low-impact nature of MNA as a groundwater restoration method must be evaluated against the effectiveness of passive groundwater restoration, which is the subject of ongoing evaluations. A lack of active MNA mechanism, insufficient site attenuation capacity, or changes in groundwater conditions may require additional action to restore groundwater or prevent cross-media impacts between groundwater and surface water. The potential for exposure to residual contamination is low since CCR will be capped and the footprint of the cap minimized.

- **Timing.** Closure of the impoundments can be completed within 1-2 years following cessation of ash placement in the impoundments. Coal will no longer be used as a fuel at BGS after December 31, 2021, and the closure of the impoundments is expected to be complete by October 17, 2023. The time required to attain the GPS for lithium and molybdenum will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The consolidation of CCR into a smaller cap area may decrease the time to reach GPS. Alternative 3 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 3:
  - IDNR Closure Permit
  - Federal, state, and local floodplain permits
  - State and local erosion control/construction storm water management permits
  - Federal and state wetland permitting may also be required.

6.4 ALTERNATIVE 4 – EXCAVATE AND DISPOSE ON-SITE WITH MNA

As described in **Section 5.4**, Alternative 4 includes closing the impoundments, excavation of CCR from the source area, and creation of a new on-site disposal that meets the design criteria for new CCR landfills required under 40 CFR 257.70

- **Performance, Reliability, Implementation, and Impacts.**
  - **Performance.** Ceasing wastewater discharges and closing the impoundments by removing and re-disposing CCR in a new lined/capped disposal area is expected to address infiltration, which is a key contributor to groundwater impacts. The consolidation of CCR into a smaller footprint may enhance the performance of the cap by further reducing the area exposed to limited post-construction infiltration through the cap. The separation from groundwater and other location criteria for the new on-site disposal facility may enhance the performance of this alternative.

MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 4 is capable of and expected to attain the GPS for lithium and molybdenum.

- **Reliability.** The expected reliability of on-site re-disposal with a composite liner and cap is good. Disposal facilities that meet the requirements in 40 CFR 257.70 or other similar requirements have been used for solid waste disposal including municipal and industrial waste for numerous years. There is significant industry experience with the design and construction of similar disposal facilities. The composite liner and cover, combined with a consolidated disposal footprint, may enhance reliability by reducing infiltration and the scale of post-closure maintenance. At the same time, post-closure maintenance is likely more complex due to maintenance of a leachate collection system and geosynthetic repairs requiring specialized personnel, material, and equipment.

- **Implementation.** The complexity of constructing the new liner and cap is moderate due to the composite design. The limited area available at the facility for developing an on-site disposal facility makes this alternative logistically complex. Significant volumes of CCR will be excavated and stored on site while the disposal facility is constructed. Significant dewatering will be required to excavate and relocate CCR to a temporary storage area. Conditioning (e.g., drying) of relocated CCR is expected to facilitate temporary storage and on-site re-disposal. Alternative 4 can likely be achieved through standard dewatering and conditioning methods, but may be impacted by the space available for these activities. Although the post-closure CCR footprint will be minimized, composite liner and cap construction may put a high demand on the local supply of suitable cap materials. The local availability of liner and cap materials will be evaluated further during remedy selection. The equipment and personnel required to implement Alternative 4 are not specialized and are generally readily available with the exception of the resources needed to install the geosynthetic portions of the composite liner and cover, which are not locally available.

- **Impacts.** Safety impacts associated with the implementation of Alternative 4 are not significantly different than other heavy civil construction projects. However, the level of disturbance required to excavate, store, and re-dispose CCR on site and the traffic required to import composite liner and cap material are not typical and likely represent an increase in safety risk due to site conditions, on-site construction traffic, and incoming/outgoing off-site construction traffic. A risk of cross-media impacts is possible due to the large volume of CCR to be excavated, stored, and relocated on site. Although the risk to surface water receptors is already low, Alternative 4 significantly reduces the potential interaction between CCR and water after closure. The ease of implementation and low-impact nature of MNA as a groundwater restoration method must be evaluated against the effectiveness of passive groundwater restoration, which is the subject of ongoing evaluations. A lack of active MNA mechanism, insufficient site attenuation capacity, or changes in groundwater conditions may require additional action to restore groundwater or prevent cross-media impacts between groundwater and surface water. The potential for exposure to residual contamination is low since CCR will be capped and the footprint of the cap minimized.

- **Timing.** Closure of the impoundments can be completed within 1-2 years following cessation of ash placement in the impoundments. Coal will no longer be used as a fuel at BGS after December 31, 2021, and the closure of the impoundments is expected to be complete by October 17, 2023; however, the time required to permit and develop the on-site disposal facility may extend this schedule. The time required to attain the GPS for lithium and molybdenum will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The consolidation of CCR into a new on-site disposal facility with a composite liner and cap may decrease the time to reach GPS. Alternative 4 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 4:
  - IDNR Closure Permit
  - IDNR Disposal Facility (Landfill) Permit
  - Federal, state, and local floodplain permits
  - State and local erosion control/construction stormwater management permits
  - Federal and state wetland permitting

6.5 ALTERNATIVE 5 – EXCAVATE AND DISPOSE IN OFF-SITE LANDFILL WITH MNA

As described in **Section 5.5**, Alternative 5 includes closing the impoundments, excavation of CCR from the source area, and transporting the CCR off site for disposal.

- **Performance, Reliability, Implementation, and Impacts.**
  - **Performance.** Ceasing wastewater discharges and closing the impoundments by removing and re-disposing CCR off site will eliminate the source material exposed to infiltration, which is a key contributor to groundwater impacts. The off-site disposal of CCR prevents further releases at BGS, but introduces the possibility of releases at the receiving facility. Although the risk to surface water receptors is already low, Alternative 5 nearly eliminates the potential interaction between CCR and water after closure. The ease of implementation and low-impact nature of MNA as a groundwater restoration method must be evaluated against the effectiveness of passive groundwater restoration, which is the subject of ongoing evaluations. A lack of active MNA mechanism, insufficient site attenuation capacity, or changes in groundwater conditions may require additional action to restore groundwater or prevent cross-media impacts between groundwater and surface water. MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 5 is capable of and expected to attain the GPS for lithium and molybdenum.

  - **Reliability.** The expected reliability of excavation and off-site disposal is good. Off-site disposal facilities are required to meet the requirements in 40 CFR 257.70 or other similar requirements, which have been used for solid waste disposal including municipal and industrial waste for numerous years. There is significant industry experience with the design and construction of these disposal facilities.

- **Implementation.** The complexity of excavating CCR for off-site disposal is low. The scale of CCR excavation (expected to exceed 1 million cy), off-site transportation, and the permitting/development of off-site disposal facility airspace makes this alternative logistically complex. Significant dewatering will be required to excavate CCR. Conditioning (e.g., drying) of excavated CCR is expected to facilitate off-site transportation and re-disposal. Alternative 5 can likely be achieved through standard dewatering and conditioning methods, but may be impacted by the space available for these activities. Although the source area at BGS is eliminated, the development of off-site disposal airspace will put a high demand on the receiving disposal facility, which may not have the current physical or logistical capacity to receive large volumes of CCR in a short period of time. The equipment and personnel required to implement on-site and off-site aspects of Alternative 5 are not specialized and are generally readily available with the exception of the resources needed to install the geosynthetic portions of the off-site composite liner and cover, which are not locally available.

- **Impacts.** Safety impacts associated with the implementation of Alternative 5 are not significantly different than other heavy civil construction projects. However, the level of disturbance required to excavate, transport, and re-dispose CCR, and the traffic required to import composite liner and cap material at the receiving disposal facility are not typical and likely represent an increase in safety risk due to large volumes of incoming/outgoing off-site construction traffic at both sites. A risk of cross-media impacts is possible due to the large volume of CCR to be excavated and transported from the site. The potential for exposure to residual contamination on site is very low since CCR will be removed; however, the off-site potential for exposure to CCR is increased due to the relocation of the source material.

- **Timing.** Closure of the impoundments can be completed within 1-2 years following cessation of ash placement in the impoundments. Coal will no longer be used as a fuel at BGS after December 31, 2021, and the closure of the impoundments is expected to be complete by October 17, 2023. However, the time required to secure the off-site disposal airspace required to complete this alternative, including potential procurement, permitting, and construction, may extend this schedule significantly. The time required to attain the GPS for lithium and molybdenum will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The removal of CCR from BGS may decrease the time to reach GPS. Alternative 5 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 5:
  - IDNR Closure Permit
  - Approval of off-site disposal facility owner or landfill permit for new off-site facility
  - Federal, state, and local floodplain permits
  - State and local erosion control/construction storm water management permits
  - Federal and state wetland permitting
  - Transportation agreements and permits (local roads and railroads)
  - State solid waste comprehensive planning approvals may also be required.

6.6 ALTERNATIVE 6 – CONSOLIDATE AND CAP WITH CHEMICAL AMENDMENT

As described in **Section 5.6**, Alternative 6 includes closing the impoundments, relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, adding a chemical amendment to the CCR to reduce the mobilization of molybdenum and lithium prior to relocating, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d).

- **Performance, Reliability, Implementation, and Impacts.**
  - **Performance.** Ceasing wastewater discharges and closing the impoundments by capping is expected to address infiltration, which is a key contributor to groundwater impacts. The consolidation of CCR into a smaller footprint may enhance the performance of the cap by further reducing the area exposed to limited post-construction infiltration through the cap. The smaller closure footprint also reduces the potential for ongoing CCR contact with groundwater. The application of a chemical amendment to the CCR that will remain on site may further reduce the potential for ongoing groundwater impacts after closure. Although the risk to surface water receptors is already low, the potential for CCR to interact with groundwater will remain after closure. Alternative 6 further reduces the potential for ongoing groundwater impacts from that interaction between CCR and water. If needed to address changes in groundwater conditions or prevent cross-media impacts between groundwater and surface water, the initial application of a chemical amendment during closure can be supplemented with additional applications in the future outside of the capped area. Alternative 6 is capable of and expected to attain the GPS for lithium and molybdenum.

  - **Reliability.** The expected reliability of capping is good. Capping is a common practice and standard remedial method for closure in place in remediation and solid waste management. There is significant industry experience with the design and construction of this method. A consolidated cap footprint may enhance reliability by reducing the scale of post-closure maintenance. Based on a review of information in the Federal Remediation Technologies Roundtable (FRTR) Technology Screening Matrix, amending source material using site-specific chemistries can be an effective means of sequestering metals to limit the future release to groundwater from residual source material. The technology can be applied to source material and groundwater plumes. The approach has been used at full scale to remediate inorganics (FRTR 2020).

  - **Implementation.** The complexity of constructing the cap is low. The logistics of moving CCR around the site to consolidate the closure footprint increases the complexity of the alternative. CCR dewatering will be required to the extent required to excavate and relocate CCR within the CCR impoundments and provide a suitable subgrade for cap construction. Some conditioning (e.g., drying) of relocated CCR is expected during on-site re-disposal. So long as an appropriate amendment chemistry can be identified for BGS, the technology and equipment used for the in-situ application or mixing as part of excavation/consolidation activities is commercially available. Alternative 6 can likely be achieved through standard dewatering and conditioning methods. Although the cap footprint will be minimized, cap construction may put a high demand on the local supply of suitable cap materials. The local availability of cap materials will be evaluated further during remedy selection. The equipment and personnel required to implement the consolidation and capping portion of Alternative 6 are not specialized and are generally readily available; however, the equipment for the in-situ chemical amendment application is more specialized and may be in high demand.

  – **Impacts.** Safety impacts associated with the implementation of Alternative 6 are not significantly different than other heavy civil construction projects. The level of disturbance required to consolidate CCR before capping may represent some increase in safety risk due to site conditions and on-site construction traffic. Some elevated risk may exist due to the use of and application of amendment chemistry, but can likely be addressed with additional worker protective measures. Cross-media impacts are expected to be limited due to the small volume of CCR expected to be relocated on site, the short duration of cap construction, the effectiveness of standard engineering controls during construction (e.g., dust control), and the lack of off-site transportation of CCR. Although the risk to surface water receptors is already low based on available data, the additional source control provided by Alternative 6 may offer further reduction of risks if groundwater conditions change. The potential for exposure to residual contamination is low since the CCR will be chemically stabilized, capped, and the footprint of the cap minimized.

- **Timing.** Closure of the impoundments can be completed within 1-2 years following cessation of ash placement in the impoundments. Coal will no longer be used as a fuel at BGS after December 31, 2021, and the closure of the impoundments is expected to be complete by October 17, 2023. The time required to attain the GPS for lithium and molybdenum will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The consolidation of CCR into a smaller cap area may decrease the time to reach GPS. Alternative 6 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 6:
  – IDNR Closure Permit
  – Federal, state, and local floodplain permits
  – Injection permits
  – State and local erosion control/construction storm water management permits
  – Federal and state wetland permitting may also be required.

6.7 ALTERNATIVE 7 – CONSOLIDATE AND CAP WITH GROUNDWATER COLLECTION

As described in **Section 5.7**, Alternative 7 includes closing the impoundments, relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, covering the CCR materials with a cap, establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d), and installing a groundwater pump and treat system to prevent the migration of and/or to recover groundwater with lithium and molybdenum concentrations greater than the GPS.

- **Performance, Reliability, Implementation, and Impacts.**
  - **Performance.** Ceasing wastewater discharges and closing the impoundments by capping is expected to address infiltration, which is a key contributor to groundwater impacts. The consolidation of CCR into a smaller footprint may enhance the performance of the cap by further reducing the area exposed to limited post-construction infiltration through the cap. The groundwater pump and treat system may further reduce the potential for downgradient migration of groundwater impacts after closure. Although the risk to surface water receptors is already low, the potential for CCR to interact with groundwater will remain after closure. Alternative 7 further reduces the risk of potential ongoing groundwater impacts from that interaction between CCR and water. The groundwater pump and treat system offers additional flexibility to address changes in groundwater conditions or prevent cross-media impacts between groundwater and surface water. Alternative 7 is capable of and expected to attain the GPS for lithium and molybdenum.

  - **Reliability.** The expected reliability of capping is good. Capping is a common practice and standard remedial method for closure in place in remediation and solid waste management. There is significant industry experience with the design and construction of this method. A consolidated cap footprint may enhance reliability by reducing the scale of post-closure maintenance. Similar to capping, groundwater pump and treat is a common method used to limit the migration of impacted groundwater or remove impacted groundwater to restore groundwater concentrations to levels below the GPS.

  - **Implementation.** The complexity of constructing the cap is low. The logistics of moving CCR around the site to consolidate the closure footprint increases the complexity of the alternative. CCR dewatering will be required to the extent required to excavate and relocate CCR within the CCR impoundments and provide a suitable subgrade for cap construction. Some conditioning (e.g., drying) of relocated CCR is expected during on-site re-disposal. The complexity of the groundwater pump and treat system is also low. Alternative 7 can likely be achieved through standard dewatering and conditioning methods. Although the cap footprint will be minimized, cap construction may put a high demand on the local supply of suitable cap materials. The local availability of cap materials will be evaluated further during remedy selection. The equipment and personnel required to implement Alternative 7 are not specialized and are generally readily available. The development, operation, maintenance, and monitoring of adequate treatment for large volumes of groundwater with relatively low concentrations of lithium and molybdenum likely increases the complexity of implementing this alternative.

  - **Impacts.** Safety impacts associated with the implementation of Alternative 7 are not significantly different than other heavy civil construction projects. The level of disturbance required to consolidate CCR before capping may represent some increase in safety risk due to site conditions and on-site construction traffic. Some elevated risk may exist due to the additional construction involved with the groundwater pump and treat system and the higher complexity of the long term maintenance required. Cross-media impacts are expected to be limited due to the small volume of CCR expected to be relocated on site, the short duration of cap construction, the effectiveness of standard engineering controls during construction (e.g., dust control), and the lack of off-site transportation of CCR.

Although the risk to surface water receptors is already low based on available data, the active nature of the groundwater plume containment provided by Alternative 7 may offer further reduction of risks if groundwater conditions change. The potential for exposure to residual contaminated source material is low since CCR will be capped and the footprint of the cap minimized. The potential exposure to contaminated groundwater is increased due to the ex-situ groundwater treatment required and the potential for worker exposure and spills.

- **Timing.** Closure of the impoundments can be completed within 1-2 years following cessation of ash placement in the impoundments. Coal will no longer be used as a fuel at BGS after December 31, 2021, and the closure of the impoundments is expected to be complete by October 17, 2023. The time required to attain the GPS for lithium and molybdenum will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The additional time required to design and install the groundwater pump and treat system is unlikely to have a significant impact on the implementation timing but may reduce the time required to attain the GPS. The consolidation of CCR into a smaller cap area may decrease the time to reach GPS. Alternative 7 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 7:
  - IDNR Closure Permit
  - Federal, state, and local floodplain permits
  - State and local well installation permits
  - NPDES permitting for post-treatment groundwater discharges
  - State and local erosion control/construction storm water management permits
  - Federal and state wetland permitting may also be required.

6.8 ALTERNATIVE 8 – CONSOLIDATE AND CAP WITH BARRIER WALL

As described in **Section 5.8**, Alternative 8 includes closing the impoundments, relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, covering the CCR materials with a cap, establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d), and installing a downgradient barrier wall to prevent the migration of groundwater with lithium and molybdenum concentrations greater than the GPS.

- **Performance, Reliability, Implementation, and Impacts.**
  - **Performance.** Ceasing wastewater discharges and closing the impoundments by capping is expected to address infiltration, which is a key contributor to groundwater impacts. The consolidation of CCR into a smaller footprint may enhance the performance of the cap by further reducing the area exposed to limited post-construction infiltration through the cap. The barrier wall may further reduce the potential for ongoing groundwater impacts after closure. Although the risk to surface water receptors is already low, the potential for CCR to interact with groundwater will remain after closure. Alternative 8 further reduces the risk of potential ongoing groundwater impacts from that interaction between CCR and water. Although it acts passively, the barrier wall reduces the risk from a more passive groundwater restoration approach such as MNA. If MNA mechanisms are not active, the site has insufficient site attenuation capacity, or groundwater

conditions change in a way that increases the potential for cross-media impacts between groundwater and surface water. Alternative 8 is capable of and expected to attain the GPS for lithium and molybdenum.

– **Reliability.** The expected reliability of capping is good. Capping is a common practice and standard remedial method for closure in place in remediation and solid waste management. There is significant industry experience with the design and construction of this method. A consolidated cap footprint may enhance reliability by reducing the scale of post-closure maintenance. A barrier wall at BGS will likely have to consist of a permeable reactive barrier (PRB) due to the lack of an impermeable layer to key a low permeability barrier wall into. In general the reliability of PRBs for containment of inorganics is favorable based on information available in the FRTR Technology Screening Matrix (FRTR 2020). The reliability of a PRB requires the identification of a suitable reactive media for the conditions at BGS and the ability to effectively locate the barrier, which are both likely but require additional evaluations. Initial reviews indicate suitable reagents for a PRB at BGS include:

  - Lithium: Sorbents including clay minerals, aluminum hydroxide, manganese oxides, and/or carbon.
  - Molybdenum: Reducing agent such as zero-valent iron.

  PRB performance can diminish over time as consumptive media is exhausted or hydraulic conditions change due to chemical precipitation or biofouling. Long-term monitoring and maintenance is required to ensure continued performance.

– **Implementation.** The complexity of constructing the cap is low. The logistics of moving CCR around the site to consolidate the closure footprint increases the complexity of the alternative. CCR dewatering will be required to the extent required to excavate and relocate CCR within the CCR impoundments and provide a suitable subgrade for cap construction. Some conditioning (e.g., drying) of relocated CCR is expected during on-site re-disposal. The complexity of the PRB wall significantly increases the level of complexity for implementing this alternative. PRB installation contractors and equipment have lengthy procurement timelines. Alternative 8 can likely be achieved through standard dewatering and conditioning methods. Although the cap footprint will be minimized, cap construction may put a high demand on the local supply of suitable cap materials. The equipment and personnel required to implement the consolidation and capping portion of Alternative 8 are not specialized and are generally readily available; however, the equipment for the barrier wall is more specialized and may be in high demand.

– **Impacts.** Safety impacts associated with the implementation of Alternative 8 are not significantly different than other heavy civil construction projects. The level of disturbance required to consolidate CCR before capping may represent some increase in safety risk due to site conditions and on-site construction traffic. Some elevated risk may exist due to the additional construction involved with the barrier wall construction and the higher complexity of the long term barrier wall performance monitoring. Cross-media impacts are expected to be limited due to the small volume of CCR expected to be relocated on site, the short duration of cap construction, the effectiveness of standard engineering controls during construction (e.g., dust control), and the lack of off-site transportation of CCR.

Although the risk to surface water receptors is already low based on available data, the enhanced nature of the passive groundwater plume containment provided by Alternative 8 may offer further reduction of risks if groundwater conditions change. The potential for exposure to residual contaminated source material is low since CCR will be capped and the footprint of the cap minimized.

- **Timing.** Closure of the impoundments can be completed within 1-2 years following cessation of ash placement in the impoundments. Coal will no longer be used as a fuel at BGS after December 31, 2021, and the closure of the impoundments is expected to be complete by October 17, 2023. The time required to attain the GPS for lithium and molybdenum will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The additional time required to design and install the barrier wall is unlikely to have a significant impact on the implementation timing but may reduce the time required to attain the GPS. The consolidation of CCR into a smaller cap area may decrease the time to reach GPS. Alternative 8 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 8:
  - IDNR Closure Permit
  - Federal, state, and local floodplain permits
  - State and local well installation permits
  - State and local erosion control/construction storm water management permits
  - Federal and state wetland permitting may also be required.

7.0 SUMMARY OF ASSESSMENT

Each of the identified corrective measure alternatives exhibit favorable and unfavorable outcomes with respect to the assessment factors that must be evaluated in accordance with 40 CFR 257.97(c). At the present time, limited impacts have been identified as described in **Section 3.0**. The nature and extent of those impacts are the subject of ongoing assessment, and IPL continues to assess remedies to meet the requirements and objectives described in 40 CFR 257.97.

8.0 REFERENCES

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HHS (2020), CCR Surface Impoundment Annual Inspection Report, Burlington Generating Station, Interstate Power and Light Company, July 2020.

United States Environmental Protection Agency (USEPA) (1998), “Solid Waste Disposal Facility Criteria Technical Manual (EPA530-R-93-017), Revised April 13, 1998,” Solid Waste and Emergency Response.

USEPA (2007), “Monitored Natural Attenuation of Inorganic Contaminants in Groundwater, Volume 1 – Technical Basis for Assessment, (EPA600-R-07-139),” Office of Research and Development, National Risk Management Laboratory, Ada, Oklahoma.

Table 1. Groundwater Elevation Summary
Burlington Generating Station / SCS Engineers Project #25220066.00

Well Number	MW-301	MW-302	MW-302A	MW-303	MW-304	MW-305	MW-306	MW-307	MW-307A	MW-308	MW-309	MW-310	MW-310A	MW-311	MW-312	MW-313	MW-313A
Top of Casing Elevation (feet amsl)	538.38	535.69	535.89	533.60	534.42	533.28	536.92	536.96	536.22	537.20	536.42	531.99	532.53	532.32	536.43	535.82	536.03
Screen Length (ft)		5.00	5					5.00	5				5			5	5
Total Depth (ft from top of casing)	31.90	29.95	62.55	28.59	25.27	29.43	34.41	28.64	61.93	30.31	27.31	18.76	48.8	22.63	27.70	32.97	63.38
Top of Well Screen Elevation (ft)	511.48	510.74	478.34	510.01	514.15	508.85	507.51	513.32	479.29	511.89	514.11	518.23	488.73	514.69	513.80	507.85	477.65
Measurement Date																	
April 20, 2016	522.63	521.91	NI	521.76	521.78	521.96	521.74	522.38	NI	521.93	522.09	525.43	NI	523.72	NM	NM	NI
June 6 & 7, 2016	521.07	521.21	NI	521.26	521.28	521.48	521.43	521.75	NI	521.43	521.39	524.13	NI	521.80	NM	NM	NI
August 16 & 17, 2016	521.81	521.35	NI	521.31	521.37	521.46	521.53	521.91	NI	521.56	521.70	524.84	NI	522.92	NM	NM	NI
October 3, 2016	527.48	527.54	NI	527.57	527.57	527.71	527.67	527.81	NI	527.62	527.57	527.58	NI	527.34	NM	NM	NI
January 9 & 10, 2017	525.38	525.50	NI	525.56	525.62	525.74	525.67	525.81	NI	525.65	525.57	525.78	NI	525.16	NM	NM	NI
April 3 & 4, 2017	523.08	522.84	NI	522.81	522.87	523.03	523.07	523.14	NI	523.07	523.10	525.52	NI	524.01	NM	NM	NI
June 12 & 13, 2017	523.21	522.84	NI	522.80	522.90	522.78	522.87	523.17	NI	522.90	522.91	524.94	NI	523.55	NM	NM	NI
August 15 & 16, 2017	519.96	519.39	NI	519.30	519.23	519.93	519.82	520.16	NI	519.80	519.93	523.89	NI	521.12	NM	NM	NI
October 16, 2017	522.13	522.20	NI	522.23	522.32	522.48	522.72	522.55	NI	522.46	522.67	525.49	NI	523.44	NM	NM	NI
May 8 & 9, 2018	525.51	525.81	NI	525.80	525.85	526.06	526.00	526.06	NI	525.62	525.54	525.79	NI	525.08	NM	NM	NI
August 13 & 14, 2018	520.19	519.87	NI	519.78	519.81	520.29	520.14	520.46	NI	520.22	520.22	523.69	NI	521.06	NM	NM	NI
October 9 &10, 2018	528.01	528.08	NI	528.78	528.82	528.97	528.95	529.08	NI	528.98	528.93	529.00	NI	528.49	NM	NM	NI
March 11, 2019	523.38	522.83	NI	522.74	522.80	NM	523.21	523.49	NI	523.13	NM	NM	NI	NM	NM	NM	NI
April 3, 2019	528.15	528.21	NI	528.22	528.27	528.36	528.40	528.63	NI	528.39	528.40	528.62	NI	528.20	NM	NM	NI
June 6, 2019	530.70	531.02	NI	531.00	531.04	TOC	531.19	531.38	NI	531.15	531.08	531.48	NI	531.07	531.08	531.05	NI
October 10 & 11, 2019	526.80	526.88	NI	526.87	526.97	527.03	527.22	527.45	NI	527.08	527.02	526.25	NI	526.68	526.97	526.97	NI
June 2-4, 2020	523.94	523.98	NI	523.97	524.02	524.12	524.45	524.62	NI	524.10	524.06	525.36	NI	524.05	524.05	524.02	NI
September 9, 2020	519.90	519.79	519.71	519.73	519.83	520.00	520.14	520.41	519.97	520.11	520.13	524.13	509.16	520.87	519.85	519.83	519.76
Ocober 19, 2020		518.94	518.79					519.33	519.00			523.81	514.13			518.70	518.61
Bottom of Well Elevation (ft)	506.48	505.74	473.34	505.01	509.15	503.85	502.51	508.32	474.29	506.89	509.11	513.23	483.73	509.69	508.73	502.85	472.65

Notes:
NM = not measured
TOC = top of casing
NI = not installed

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Table 2. CCR Rule Groundwater Samples Summary
Burlington Generating Station / SCS Engineers Project #25218201.00

Sample Dates	Downgradient Wells														Background Wells		
	MW-301	MW-302	MW-302A	MW-303	MW-304	MW-305	MW-306	MW-307	MW-307A	MW-308	MW-309	MW-312	MW-313	MW-313A	MW-310	MW310A	MW-311
4/20-21/2016	B	B	--	B	B	B	B	B	--	B	B	--	--	--	B	--	B
6/6-7/2016	B	B	--	B	B	B	B	B	--	B	B	--	--	--	B	--	B
8/16-17/2016	B	B	--	B	B	B	B	B	--	B	B	--	--	--	B	--	B
10/3/2016	B	B	--	B	B	B	B	B	--	B	B	--	--	--	B	--	B
1/9-10/2017	B	B	--	B	B	B	B	B	--	B	B	--	--	--	B	--	B
4/3-4/2017	B	B	--	B	B	B	B	B	--	B	B	--	--	--	B	--	B
6/12-13/2017	B	B	--	B	B	B	B	B	--	B	B	--	--	--	B	--	B
8/15-16/2017	B	B	--	B	B	B	B	B	--	B	B	--	--	--	B	--	B
10/16-17/2017	D	D	--	D	D	D	D	D	--	D	D	--	--	--	D	--	D
5/8-9/2018	A	A	--	A	A	A	A	A	--	A	A	--	--	--	A	--	A
8/13-14/2018	A	A	--	A	A	A	A	A	--	A	A	--	--	--	A	--	A
10/9-10/2018	A	A	--	A	A	A	A	A	--	A	A	--	--	--	A	--	A
3/12-13/2019	R	R	--	R	R	--	R	R	--	R	--	--	--	--	--	--	--
4/3-4/2019	A	A	--	A	A	A	A	A	--	A	A	--	--	--	A	--	A
6/6/2019	--	--	--	--	--	--	--	--	--	--	--	A	A	--	--	--	--
10/10-11/2019	A	A	--	A	A	A	A	A	--	A	A	A	A	--	A	--	A
6/2-4/2020	A	A	--	A	A	A	A	A	--	A	A	A	A	--	A	--	A
09/09/20	--	--	A	--	--	--	--	--	A	--	--	--	--	A	--	A	--
10/14-16/2020	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

Abbreviations:
A = Required by Assessment Monitoring Program
B = Background Sample
-- = Not applicable
D = Required by Detection Monitoring Program
R = Resample Event

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Table 3. Groundwater Analytical Results Summary - Assessment Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25220066.00

Parameter Name	UPL Method	UPL	GPS	Background Wells																		Compliance Wells								
				MW-310								MW-310A*%		MW-311								MW-301								
				10/16/2017	5/9/2018	8/14/2018	10/10/2018	4/4/2019	10/11/2019	6/2/2020	10/14/2020	9/9/2020	10/16/2020	10/16/2017	5/9/2018	8/14/2018	10/10/2018	4/4/2019	10/11/2019	6/2/2020	10/14/2020	10/16/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020	10/16/2020
Appendix III																														
Boron, ug/L	NP	2,950		305	217	256	268	560	380	500	290	2,200	1200	2,810	2,200	2,580	2,820	1,800	2,800	2,500	3500	9,900 M1	9,140	12,800	8,040	NA	12,000	8,100	10,000	12000
Calcium, mg/L	P	210		105	104	102	107	120	120	130	92	150	62	145	173	156	130	200	150	190	140	140 M1	85.3	174	103	NA	150	130	140	220
Chloride, mg/L	P	209		38.3	24.4	33.8	67.1	88	59	87	17	18	16	50.9	79.9	69.9	54	110	65	120	61	22.0	22.7	21.7	21.5	NA	21	20	22	20
Fluoride, mg/L	P	0.427		0.39	0.33	0.39	0.4	0.55	0.34 J	0.65	<0.23	0.27 J	<0.23	0.36	0.31	0.36	0.35	0.41 J	0.37 J	0.64	<0.23	0.27	0.36	0.52	0.26	NA	0.77	<0.23	0.26 J	<0.23
Field pH, Std. Units	P	8.17		7.92	7.46	7.44	7.20	7.84	6.95	7.30	7.34	7.33	NA	8.27	7.26	7.33	7.49	7.64	7.07	7.10	7.41	7.58	7.4	7.91	7.34	6.38	7.53	6.85	6.99	7.07
Sulfate, mg/L	P	457		35.1	28.8	27.2	37.9	21	51	100	19	100	130	119	176	144	127	230	130	220	110	454	188	187	358	NA	190	390	250	170
Total Dissolved Solids, mg/L	P	1,113		445	462	472	512	600	410	590	390	570	620	615	864	777	678	980	590	950	640	780	568	960	656	NA	890	690	910	970
Appendix IV		UPL	GPS																											
Antimony, ug/L	P*	0.17	6	NA	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58	1.9	1.1	1.5	NA	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58	<0.51	NA	<0.026	<0.15	0.080 J	NA	<0.53	<0.53	<0.58	<0.51
Arsenic, ug/L**	P	114.9	114.9	NA	57.8	56.2	62.1	65	61	55	63	15	5.1	NA	14.0	15.7	15.2	19	18	19	15	NA	34.9	40.1	37.7	NA	42	40	46	54
Barium, ug/L	P	1,147	2,000	NA	403	398	450	560	500	550	400	290	90	NA	256	239	214	280	210	300	220	NA	198	420	276	NA	380	320	330	500
Beryllium, ug/L	NP*	0.036	4	NA	<0.012	<0.12	<0.089	<0.27	<0.27	<0.27	<0.27	2.3	<0.27	NA	<0.023 D3	<0.12	<0.089	<0.27	<0.27	<0.27	<0.27	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27	<0.27
Cadmium, ug/L	NP*	0.025	5	NA	<0.018	<0.070	<0.033	<0.077	<0.039	<0.039	<0.049	0.69	0.062 J	NA	<0.018	<0.070	<0.033	<0.077	<0.039	<0.039	<0.049	NA	0.040 J	<0.070	<0.033	NA	<0.077	<0.039	<0.039	<0.049
Chromium, ug/L	P*	0.090	100	NA	0.16 J,B	<0.19	0.082 J	<0.98	<0.98	<1.1	<1.1	5.4	<1.1	NA	0.20 J,B	0.22 J	0.78 J	<0.98	<0.98	<1.1	<1.1	NA	0.25 J,B	0.36 J	0.12 J	NA	<0.98	<0.98	<1.1	<1.1
Cobalt, ug/L	P	3.87	6	NA	1.2	1.4	1.4	1.9	1.9	2.3	1.5	28	3.4	NA	0.30 J	0.37 J	0.57 J	0.45 J	0.27 J	0.81	0.28 J	NA	0.15 J	0.45 J	0.10 J	NA	0.44 J	0.18 J	0.31 J	0.7
Fluoride, mg/L	P	0.427	4	NA	0.33	0.39	0.4	0.55	0.34 J	0.65	<0.23	0.27 J	<0.23	NA	0.31	0.36	0.35	0.41 J	0.37 J	0.64	<0.23	NA	0.36	0.52	0.26	NA	0.77	<0.23	0.26 J	<0.23
Lead, ug/L	NP*	0.64	15	NA	0.044 J	<0.12	<0.13	<0.27	<0.27	<0.27	<0.11	20	3.5	NA	0.043 J	0.13 J	0.48 J,B	0.37 J	<0.27	1.1	<0.11	NA	0.17 J	0.13 J	<0.13	NA	<0.27	<0.27	<0.27	<0.11
Lithium, ug/L	NP*	7.7	40	NA	<4.6	5.3 J	<4.6	<2.7	<2.7	<2.3	<2.5	32	36	NA	<4.6	<4.6	<4.6	<2.7	<2.7	<2.3	<2.5	NA	17.8	18.9	24.5	NA	13	26	16	10
Mercury, ug/L	DQ	DQ	2	NA	<0.090	NA	<0.090	<0.10	NA	<0.10	<0.10	<0.10	<0.10	NA	<0.090	NA	<0.090	<0.10	NA	0.13 J	<0.10	NA	<0.090	NA	<0.090	NA	<0.10	NA	<0.10	<0.10
Molybdenum, ug/L	NP	14.7	100	NA	4.2	4	4.6	5.2	6.0	5.8	3.6	19	33	NA	11.6	13.9	16.3	8.5	15	11	23	NA	113	81.7	120	62.7	77	130	110	67
Selenium, ug/L	P*	0.28	50	NA	0.14 J	<0.16	0.19 J	<1.0	<1.0	<1.0	<1.0	1.5 J	<0.10	NA	0.17 J	0.18 J	0.23 J	<1.0	<1.0	<1.0	<1.0	NA	0.25 J	0.28 J	0.13 J	NA	<1.0	<1.0	<1.0	<1.0
Thallium, ug/L	NP*	0.35	2	NA	<0.036	NA	<0.099	<0.27	NA	<0.26	NA	<0.26	NA	NA	<0.036	NA	<0.099	<0.27	NA	<0.26	NA	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26	NA
Radium 226/228 Combined, pCI/L	P	3.36	5	NA	0.755	1.55	2.56	1.19	0.490	0.844	Pending	4.91	Pending	NA	0.987	0.969	0.819	0.815	0.599	0.802	Pending	NA	0.712	1.15	1.50	NA	1.15	1.03	0.928	Pending
Additional Parameter Collected for Selection of Remedy																														
Lithium, dissolved,[#] ug/L				NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Iron, dissolved,[#] ug/L				NA	NA	NA	NA	NA	NA	NA	16,000	NA	<50.0	NA	NA	NA	NA	NA	NA	NA	16,000	NA	NA	NA	NA	NA	NA	NA	NA	34,000
Iron, ug/L				NA	NA	NA	NA	NA	NA	NA	18,000	NA	1,600	NA	NA	NA	NA	NA	NA	NA	16,000	NA	NA	NA	NA	NA	NA	NA	NA	34,000
Magnesium, dissolved,[#]				NA	NA	NA	NA	NA	NA	NA		NA		NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA	
Magnesium, ug/L				NA	NA	NA	NA	NA	NA	NA	24,000	NA	25,000	NA	NA	NA	NA	NA	NA	NA	30,000	NA	NA	NA	NA	NA	NA	NA	NA	63,000
Manganese, dissolved,[#] ug/L				NA	NA	NA	NA	NA	NA	NA	4,000	NA	420	NA	NA	NA	NA	NA	NA	NA	4,300	NA	NA	NA	NA	NA	NA	NA	NA	13,000
Manganese, ug/L				NA	NA	NA	NA	NA	NA	NA	4,400	NA	470	NA	NA	NA	NA	NA	NA	NA	4,200	NA	NA	NA	NA	NA	NA	NA	NA	12,000
Molybdenum, dissolved,[#] ug/L	UPL or GPS not applicable			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	66.0
Potassium, ug/L				NA	NA	NA	NA	NA	NA	NA	2,700	NA	6,900	NA	NA	NA	NA	NA	NA	NA	2,300	NA	NA	NA	NA	NA	NA	NA	NA	4,100
Sodium, ug/L				NA	NA	NA	NA	NA	NA	NA	13,000	NA	####	NA	NA	NA	NA	NA	NA	NA	36,000	NA	NA	NA	NA	NA	NA	NA	NA	45,000
Bicarbonate Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	330	NA	410	NA	NA	NA	NA	NA	NA	NA	380	NA	NA	NA	NA	NA	NA	NA	NA	760
Carbonate Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	<3.80	NA	<3.8	NA	NA	NA	NA	NA	NA	NA	<3.80	NA	NA	NA	NA	NA	NA	NA	NA	<3.80
Total Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	330	NA	410	NA	NA	NA	NA	NA	NA	NA	380	NA	NA	NA	NA	NA	NA	NA	NA	760

4.4	Blue highlighted cell indicates the compliance well result exceeds the UPL (background) and the LOQ.
30.8	Yellow highlighted cell indicates the compliance well result exceeds the GPS.
17	Grayscale indicates Additional Parameters sampled for selection of remedy and evaluation of Monitored Natural Attenuation.

See page 5 for Notes and Abbreviations

Table 3. Groundwater Analytical Results Summary - Assessment Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25220066.00

Compliance Wells

Parameter Name	UPL Method	UPL	GPS	MW-302									MW-302A	
				10/17/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020	10/16/2020	9/9/2020	10/16/2020
Appendix III														
Boron, ug/L	NP	2,950		10,000	10,200	10,000	10,400	NA	12,000	11,000	13,000	11000	11,000	11000
Calcium, mg/L	P	210		231	231	210	219	NA	220	220	210	200	120	130
Chloride, mg/L	P	209		16.4	14.1	14.7	13.5	NA	13	11	12	10	27	23
Fluoride, mg/L	P	0.427		0.11 J	0.11 J	<0.063	<0.19	NA	0.37 J	<0.23	<0.23	<0.23	<0.23	<0.23
Field pH, Std. Units	P	8.17		8.72	8.19	9.32	7.89	6.94	8.70	7.49	7.88	7.87	7.31	7.26
Sulfate, mg/L	P	457		541	553	542	658	NA	510	510	490	460	340	330
Total Dissolved Solids, mg/L	P	1,113		951	1,080	1,000	1,030	NA	1,000	960	1,000	910	730	710
Appendix IV		UPL	GPS											
Antimony, ug/L	P*	0.17	6	NA	<0.026	<0.15	0.082 J	NA	<0.53	<0.53	<0.58	<0.51	<0.51	1.7
Arsenic, ug/L**	P	114.9	114.9	NA	56.2	49.6	76.4	NA	53	73	110	76	2.9	2.9
Barium, ug/L	P	1,147	2,000	NA	363	340	180	NA	320	260	340	250	270	280
Beryllium, ug/L	NP*	0.036	4	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27
Cadmium, ug/L	NP*	0.025	5	NA	0.037 J	<0.070	0.040 J	NA	<0.077	<0.039	0.045 J	0.11	<0.049	0.065 J
Chromium, ug/L	P*	0.090	100	NA	0.22 J, B	0.33 J	0.097 J	NA	<0.98	<0.98	<1.1	<1.1	<1.1	<1.1
Cobalt, ug/L	P	3.87	6	NA	0.19 J	0.15 J	0.18 J	NA	0.19 J	0.23 J	0.21 J	0.26 J	0.12 J	0.11 J
Fluoride, mg/L	P	0.427	4	NA	0.11 J	<0.063	<0.19	NA	0.37 J	<0.23	<0.23	<0.23	<0.23	<0.23
Lead, ug/L	NP*	0.64	15	NA	0.17 J	<0.12	<0.13	NA	0.58	<0.27	<0.27	0.17 J	0.11 J	<0.11
Lithium, ug/L	NP*	7.7	40	NA	65.4	61.4	57.8	59.9	56	57	55	64	11	11
Mercury, ug/L	DQ	DQ	2	NA	<0.090	NA	<0.090	NA	<0.10	NA	<0.10	<0.10	<0.10	<0.10
Molybdenum, ug/L	NP	14.7	100	NA	118	121	122	123	100	100	140	130	120	110
Selenium, ug/L	P*	0.28	50	NA	0.25 J	0.22 J	0.23 J	NA	<1.0	<1.0	<1.0	1.1 J	<1.0	<1.0
Thallium, ug/L	NP*	0.35	2	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26	NA	<0.26	NA
Radium 226/228 Combined, pCI/L	P	3.36	5	NA	1.51	1.53	2.15	NA	0.872	0.644	0.626	Pending	1.15	Pending
Additional Parameter Collected for Selection of Remedy														
Lithium, dissolved,# ug/L	UPL or GPS not applicable			NA	NA	NA	NA	NA	NA	NA	NA	64.0	NA	NA
Iron, dissolved,# ug/L				NA	NA	NA	NA	NA	NA	NA	NA	3,200	NA	8,600
Iron, ug/L				NA	NA	NA	NA	NA	NA	NA	NA	2,900	NA	8,400
Magnesium, dissolved,#				NA	NA	NA	NA	NA	NA	NA	NA		NA	
Magnesium, ug/L				NA	NA	NA	NA	NA	NA	NA	NA	18,000	NA	28,000
Manganese, dissolved,# ug/L				NA	NA	NA	NA	NA	NA	NA	NA	1,600	NA	3,800
Manganese, ug/L				NA	NA	NA	NA	NA	NA	NA	NA	1,400	NA	3,600
Molybdenum, dissolved,# ug/L				NA	NA	NA	NA	NA	NA	NA	NA	120	NA	120
Potassium, ug/L				NA	NA	NA	NA	NA	NA	NA	NA	12,000	NA	3,600
Sodium, ug/L				NA	NA	NA	NA	NA	NA	NA	NA	24,000	NA	34,000
Bicarbonate Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	NA	240	NA	150
Carbonate Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	NA	<3.80	NA	<3.80
Total Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	NA	240	NA	150

Parameter Name	MW-303									MW-304								
	10/17/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020	10/16/2020	10/17/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/3/2020	10/15/2020
Appendix III																		
Boron, ug/L	25,400	22,900	24,500	24,500	NA	22,000	21,000	23,000	19000	5,580	5,140	5,440	6,180	NA	6,300	5,100	6,400	7400
Calcium, mg/L	84.5	87.0	85.9	87.8	NA	86	91	120	120	103	107	102	88.5	NA	72	140	150	150
Chloride, mg/L	15.3	15.1	15.7	16.3	NA	15	16	18	17	46.5	58.1	25.9	50.3	NA	39	25	21	21
Fluoride, mg/L	0.25	0.22	0.44	0.27	NA	0.43 J	<0.23	0.27 J	<0.23	0.12 J	0.11 J	0.13 J	<0.19	NA	0.35 J	<0.23	<0.23	<0.23
Field pH, Std. Units	8.59	7.51	8.03	7.10	6.46	7.79	7.13	7.12	7.19	9.52	8.51	7.6	9.01	6.94	8.56	7.17	7.23	8.46
Sulfate, mg/L	42.1	128	78.7	31.8	NA	120	84	100	190	248	273	188	271	NA	140	220	250	420
Total Dissolved Solids, mg/L	436	502	520	462	NA	540	420	640	630	540	657	551	537	NA	460	710	750	820
Appendix IV																		
Antimony, ug/L	NA	<0.026	<0.15	<0.078	NA	<0.53	<0.53	<0.58	0.57 J	NA	0.75 J	0.3 J	0.77 J	NA	0.66 J	<0.53	<0.58	0.52 J
Arsenic, ug/L**	NA	7.9	52	29.8	NA	6.4	17	18	14	NA	57.2	45.4	58.3	NA	59	36	35	49
Barium, ug/L	NA	412	354	415	NA	440	440	610	480	NA	115	140	92	NA	90	210	220	170
Beryllium, ug/L	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27	<0.27	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27	<0.27
Cadmium, ug/L	NA	0.028 J	<0.070	<0.033	NA	<0.077	<0.039	<0.039	<0.049	NA	<0.018	<0.070	0.054 J	NA	<0.077	<0.039	<0.039	<0.049
Chromium, ug/L	NA	0.27 J,B	0.29 J	0.69 J	NA	<0.98	<0.98	<1.1	<1.1	NA	0.22 J,B	0.34 J	0.091 J	NA	<0.98	<0.98	<1.1	<4.4
Cobalt, ug/L	NA	0.31 J	0.46 J	0.62 J	NA	0.36 J	0.45 J	0.56	0.49 J	NA	0.098 J	<0.15	0.19 J	NA	0.11 J	0.13 J	0.15 J	<0.36
Fluoride, mg/L	NA	0.22	0.44	0.27	NA	0.43 J	<0.23	0.27 J	<0.23	NA	0.11 J	0.13 J	<0.19	NA	0.35 J	<0.23	<0.23	<0.23
Lead, ug/L	NA	0.21 J	0.22 J	0.54 J,B	NA	0.49 J	<0.27	0.29 J	0.18 J	NA	<0.033	<0.12	<0.13	NA	<0.27	<0.27	<0.27	<0.11
Lithium, ug/L	NA	50.7	42.1	35.8	51.6	52	46	48	59	NA	63.8	34.3	82.4	35.9	52	38	47	92
Mercury, ug/L	NA	<0.090	NA	<0.090	NA	<0.10	NA	<0.10	<0.10	NA	<0.090	NA	<0.090	NA	<0.10	NA	0.11 J, F1	<0.10
Molybdenum, ug/L	NA	75.4	77.9	56.5	NA	110	76	66	84	NA	126	74.9	113	47.4	58	47	45	140
Selenium, ug/L	NA	0.19 J	0.24 J	0.33 J	NA	<1.0	<1.0	<1.0	<1.0	NA	0.24 J	0.21 J	0.26 J	NA	<1.0	<1.0	<1.0	<4.0
Thallium, ug/L	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26	NA	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26	NA
Radium 226/228 Combined, pCI/L	NA	1.64	1.79	1.91	NA	1.26	1.04	0.892	Pending	NA	0.589	0.725	0.706	NA	0.408	0.781	0.573	Pending
Additional Parameter Collected for Selection of Remedy																		
Lithium, dissolved,# ug/L	NA	NA	NA	NA	NA	NA	NA	NA	59.0	NA	NA	NA	NA	NA	NA	NA	NA	93.0
Iron, dissolved,# ug/L	NA	NA	NA	NA	NA	NA	NA	NA	8,700	NA	NA	NA	NA	NA	NA	NA	NA	720
Iron, ug/L	NA	NA	NA	NA	NA	NA	NA	NA	8,500	NA	NA	NA	NA	NA	NA	NA	NA	660
Magnesium, dissolved,#	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA	
Magnesium, ug/L	NA	NA	NA	NA	NA	NA	NA	NA	21,000	NA	NA	NA	NA	NA	NA	NA	NA	3,800
Manganese, dissolved,# ug/L	NA	NA	NA	NA	NA	NA	NA	NA	3,900	NA	NA	NA	NA	NA	NA	NA	NA	440
Manganese, ug/L	NA	NA	NA	NA	NA	NA	NA	NA	3,700	NA	NA	NA	NA	NA	NA	NA	NA	380
Molybdenum, dissolved,# ug/L	NA	NA	NA	NA	NA	NA	NA	NA	85.0	NA	NA	NA	NA	NA	NA	NA	NA	140
Potassium, ug/L	NA	NA	NA	NA	NA	NA	NA	NA	22,000	NA	NA	NA	NA	NA	NA	NA	NA	14,000
Sodium, ug/L	NA	NA	NA	NA	NA	NA	NA	NA	30,000	NA	NA	NA	NA	NA	NA	NA	NA	51,000
Bicarbonate Alkalinity, mg/L	NA	NA	NA	NA	NA	NA	NA	NA	290	NA	NA	NA	NA	NA	NA	NA	NA	130
Carbonate Alkalinity, mg/L	NA	NA	NA	NA	NA	NA	NA	NA	<3.80	NA	NA	NA	NA	NA	NA	NA	NA	<3.80
Total Alkalinity, mg/L	NA	NA	NA	NA	NA	NA	NA	NA	290	NA	NA	NA	NA	NA	NA	NA	NA	130

4.4	Blue highlighted cell indicates the compliance well result exceeds the UPL (background) and the LOQ.
30.8	Yellow highlighted cell indicates the compliance well result exceeds the GPS.
17	Grayscale indicates Additional Parameters sampled for selection of remedy and evaluation of Monitored Natural Attenuation.

See page 5 for Notes and Abbreviations

Table 3. Groundwater Analytical Results Summary - Assessment Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25220066.00

Parameter Name	UPL Method	UPL	GPS	Compliance Wells MW-305								MW-306									MW-307									MW-307A	
				10/16/2017	5/9/2018	8/13/2018	10/10/2018	4/3/2019	10/11/2019	6/3/2020	10/15/2020	10/16/2017	5/9/2018	8/14/2018	10/10/2018	3/11/2019	4/3/2019	10/11/2019	6/4/2020	10/15/2020	10/16/2017	5/9/2018	8/14/2018	10/10/2018	3/11/2019	4/3/2019	10/11/2019	6/4/2020	10/15/2020	9/9/2020	10/14/2020
Appendix III																															
Boron, ug/L	NP	2,950		2,480	2,000	2,400	2,040	2,000	2,100	2,200	2400	3,680	3,480	3,430	3,350	NA	2,900	3,100	3,200	3200	3,920	3,910	4,090	3,720	NA	3,400	3,700	3,600	3400	3,900	4100
Calcium, mg/L	P	210		92.2	82.5	103	93.2	83	90	120	120	35.3	32.0	33.5	34.6	NA	37	38	41	37	31.3	27.3	27.2	27.6	NA	29	31	37	36	10	11
Chloride, mg/L	P	209		35.8	34.8	34.8	34.9	33	33	36	32	20.6	20.3	20.6	20.9	NA	21	20	21	18	20.8	20.1	20.1	21.6	NA	21	19	21	17	34	31
Fluoride, mg/L	P	0.427		0.43	0.48	0.45	0.44	0.75	0.37 J	0.45 J	<0.23	0.15 J	0.12 J	0.1 J	<0.19	NA	0.36 J	<0.23	<0.23	<0.23	0.13 J	0.11 J	0.094 J	<0.19	NA	0.51	<0.23	<0.23	<0.23	<0.23	<0.23
Field pH, Std. Units	P	8.17		7.78	7.72	7.81	7.29	7.80	7.36	7.12	7.23	10.66	6.80	10.33	6.04	6.27	6.69	10.53	10.48	10	10.46	10.3	10.12	9.88	9.71	10.39	10.14	10.03	10.05	7.83	7.8
Sulfate, mg/L	P	457		24.6	11.7	24.8	19.6	10	8.8	33	54	97.5	107	111	121	NA	110	110	120	71	126	119	119	143	NA	120	130	180	160	110	110
Total Dissolved Solids, mg/L	P	1,113		437	441	542	490	470	490	640	600	301	396	303	289	NA	320	290	320	300	341	347	340	336	NA	420	340	390	370	370	360
Appendix IV		UPL	GPS																												
Antimony, ug/L	P*	0.17	6	NA	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58	<0.51	NA	1.2	1.4	1.2	NA	1.1	1.2	1.1	0.9 J	NA	0.50 J	0.58 J	0.62 J	NA	<0.53	<0.53	<0.58	0.56 J	<0.51	<0.51
Arsenic, ug/L**	P	114.9	114.9	NA	0.28 J	0.39 J	0.44 J	<0.75	<0.75	<0.88	<0.88	NA	52.6	48	50.6	NA	50	46	50	46	NA	54.3	52.3	52.8	NA	43	47	47	47	<0.88	<0.88
Barium, ug/L	P	1,147	2,000	NA	173	219	197	160	180	230	250	NA	13.6	15.5	14.8	NA	14	14	16	16	NA	32.3	29	31.1	NA	29	31	36	39	45	47
Beryllium, ug/L	NP*	0.036	4	NA	<0.012	<0.12	<0.089	<0.27	<0.27	<0.27	<0.27	NA	<0.012	0.14 J	<0.089	NA	<0.27	<0.27	<0.27	<0.27	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27
Cadmium, ug/L	NP*	0.025	5	NA	<0.018	<0.070	<0.033	<0.077	<0.039	<0.039	<0.049	NA	0.029 J	0.18 J	<0.033	NA	<0.077	<0.039	<0.039	<0.049	NA	0.12 J	<0.070	0.068 J	NA	<0.077	<0.039	0.044 J	<0.049	0.058 J	0.052 J
Chromium, ug/L	P*	0.090	100	NA	0.25 J,B	0.21 J	0.27 J	<0.98	<0.98	<1.1	<1.1	NA	0.24 J,B	0.25 J	0.18 J	NA	<0.98	<0.98	<1.1	<1.1	NA	0.27 J,B	0.36 J	0.15 J	NA	<0.98	<0.98	<1.1	<1.1	<1.1	<1.1
Cobalt, ug/L	P	3.87	6	NA	0.14 J	<0.15	0.17 J	0.16 J	0.13 J	0.18 J	0.15 J	NA	0.035 J	0.18 J	<0.062	NA	<0.091	<0.091	<0.091	<0.091	NA	0.033 J	<0.15	<0.062	NA	<0.091	<0.091	<0.091	<0.091	0.11 J	0.15 J
Fluoride, mg/L	P	0.427	4	NA	0.48	0.45	0.44	0.75	0.37 J	0.45 J	<0.23	NA	0.12 J	0.1 J	<0.19	NA	0.36 J	<0.23	<0.23	<0.23	NA	0.11 J	0.094 J	<0.19	NA	0.51	<0.23	<0.23	<0.23	<0.23	<0.23
Lead, ug/L	NP*	0.64	15	NA	0.034 J	<0.12	0.20 J,B	<0.27	<0.27	<0.27	<0.11	NA	0.26 J	0.69 J	0.37 J,B	NA	<0.27	0.44 J	0.33 J	0.43 J	NA	0.39 J	0.43 J	0.49 J,B	NA	0.37 J	0.41 J	<0.27	0.19 J	0.69	0.63
Lithium, ug/L	NP*	7.7	40	NA	27.8	33.6	27.6	29	26	28	34	NA	36.6	46.8	41.4	39.2	45	46	43	42	NA	47.8	56.1	45.4	50.7	50	48	48	51	6.8 J	8.3 J
Mercury, ug/L	DQ	DQ	2	NA	<0.090	NA	<0.090	<0.10	NA	0.12 J	<0.10	NA	<0.090	NA	<0.090	NA	<0.10	NA	0.10 J	<0.10	NA	<0.090	NA	<0.090	NA	<0.10	NA	0.12 J	<0.10	<0.10	<0.10
Molybdenum, ug/L	NP	14.7	100	NA	0.87 J	1	0.72 J	<1.1	<1.1	<1.1	1.1 J	NA	84.7	82.9	83.5	NA	78	84	86	82	NA	154	155	159	156	100	130	130	140	110	120
Selenium, ug/L	P*	0.28	50	NA	0.24 J	0.16 J	0.16 J	<1.0	<1.0	<1.0	<1.0	NA	0.66 J	0.97 J	0.6 J	NA	<1.0	<1.0	<1.0	<1.0	NA	0.36 J	0.41 J	0.36 J	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thallium, ug/L	NP*	0.35	2	NA	<0.036	NA	<0.099	<0.27	NA	<0.26	NA	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26	NA	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26	NA	<0.26	NA
Radium 226/228 Combined, pCI/L	P	3.36	5	NA	2.11	1.78	1.22	0.519	0.441	0.759	Pending	NA	0.482	1.04	1.10	NA	0.165	0.526	0.0769	Pending	NA	0.0587	0.415	1.43	NA	0.447	0.232	0.277	Pending	0.605	Pendin g
Additional Parameter Collected for Selection of Remedy																															
Lithium, dissolved,# ug/L	UPL or GPS not applicable			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	42	NA	NA	NA	NA	NA	NA	NA	NA	50.0	NA	NA
Iron, dissolved,# ug/L				NA	NA	NA	NA	NA	NA	NA	3,000	NA	NA	NA	NA	NA	NA	NA	NA	<50.0	NA	NA	NA	NA	NA	NA	NA	NA	<50.0	NA	460
Iron, ug/L				NA	NA	NA	NA	NA	NA	NA	3,000	NA	NA	NA	NA	NA	NA	NA	NA	<50.0	NA	NA	NA	NA	NA	NA	NA	NA	<50.0	NA	610
Magnesium, dissolved,#				NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA		NA	
Magnesium, ug/L				NA	NA	NA	NA	NA	NA	NA	26,000	NA	NA	NA	NA	NA	NA	NA	NA	<100	NA	NA	NA	NA	NA	NA	NA	NA	<100	NA	1,700
Manganese, dissolved,# ug/L				NA	NA	NA	NA	NA	NA	NA	2,900	NA	NA	NA	NA	NA	NA	NA	NA	<4.0	NA	NA	NA	NA	NA	NA	NA	NA	6.60 J	NA	420
Manganese, ug/L				NA	NA	NA	NA	NA	NA	NA	2,800	NA	NA	NA	NA	NA	NA	NA	NA	5.4 J	NA	NA	NA	NA	NA	NA	NA	NA	6.40 J	NA	430
Molybdenum, dissolved,# ug/L				NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	140	NA	120
Potassium, ug/L				NA	NA	NA	NA	NA	NA	NA	5,700	NA	NA	NA	NA	NA	NA	NA	NA	20000	NA	NA	NA	NA	NA	NA	NA	NA	36,000	NA	3,100
Sodium, ug/L				NA	NA	NA	NA	NA	NA	NA	54,000	NA	NA	NA	NA	NA	NA	NA	NA	46000	NA	NA	NA	NA	NA	NA	NA	NA	54,000	NA	####
Bicarbonate Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	470	NA	NA	NA	NA	NA	NA	NA	NA	52	NA	NA	NA	NA	NA	NA	NA	NA	<1.90	NA	110
Carbonate Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	<3.80	NA	NA	NA	NA	NA	NA	NA	NA	82	NA	NA	NA	NA	NA	NA	NA	NA	79.0	NA	<1.9
Total Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	470	NA	NA	NA	NA	NA	NA	NA	NA	130	NA	NA	NA	NA	NA	NA	NA	NA	84.0	NA	110

4.4	Blue highlighted cell indicates the compliance well result exceeds the UPL (background) and the LOQ.
30.8	Yellow highlighted cell indicates the compliance well result exceeds the GPS.
17	Grayscale indicates Additional Parameters sampled for selection of remedy and evaluation of Monitored Natural Attenuation.

See page 5 for Notes and Abbreviations

Table 3. Groundwater Analytical Results Summary - Assessment Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25220066.00

				Compliance Wells																										
Parameter Name	UPL Method	UPL	GPS	MW-308									MW-309								MW-312				MW-313				MW-313A	
				10/17/2017	5/9/2018	8/13/2018	10/10/2018	3/12/2019	4/3/2019	10/10/2019	6/4/2020	10/14/2020	10/17/2017	5/9/2018	8/14/2018	10/10/2018	4/3/2019	10/11/2019	6/3/2020	10/14/2020	6/6/2019	10/10/2019	6/3/2020	10/15/2020	6/6/2019	10/10/2019	6/3/2020	10/15/2020	9/9/2020	########
Appendix III																														
Boron, ug/L	NP	2,950		4,850	5,030	5,070	4,710	NA	4,300	4,500	4,700	4500	4,400	4,720	4,930	4,720	4,200	4,300	4,400	4400	6,100	6,600	6,700	6500	7,400	8,500	8,600	7600	4,300	4200
Calcium, mg/L	P	210		32.6	28.7	28.7	28.5	NA	32	30	34	37	101	83.6	74.1	72.4	73	68	82	59	67	71	74	78	110	120	120	110	48	44
Chloride, mg/L	P	209		38.2	36.2	36.7	35.9	NA	38	40	58	45	85.4	112	111	105	100	74	84	64	27	25	36	23	85	51	83	50	210	200
Fluoride, mg/L	P	0.427		0.17 J	0.17 J	0.16 J	<0.19	NA	0.37 J	<0.23	0.37 J	<0.23	0.47	0.40	0.43	0.40	0.71	0.29 J	0.58	<0.23	1.1	0.25 J	0.57	<0.23	0.33 J	0.28 J	0.52	<0.23	<0.23	<0.23
Field pH, Std. Units	P	8.17		9.75	9.75	9.86	9.82	7.72	9.97	9.42	9.65	9.7	8.50	7.25	7.39	7.46	7.45	7.19	7.09	7.61	6.99	7.19	7.13	7.37	6.94	7.06	7.03	7.16	7.6	7.64
Sulfate, mg/L	P	457		177	164	167	193	NA	170	160	190	160	149	107	98.9	111	78	160	180	160	220	230	200	210	210	210	230	170	200	190
Total Dissolved Solids, mg/L	P	1,113		472	494	468	440	NA	490	400	470	460	671	688	668	650	650	610	730	550	540	510	670	560	700	520	830	640	730	660
Appendix IV		**UPL**	**GPS**																											
Antimony, ug/L	P*	0.17	6	NA	0.32 J	0.32 J	0.36 J	NA	<0.53	<0.53	<0.58	<0.51	NA	<0.026	<0.15	<0.078	<0.53	<0.53	<0.58	<0.51	<0.53	<0.53	<0.58	<0.51	<0.53	<0.53	<0.58	<0.51	<0.51	<0.51
Arsenic, ug/L**	P	114.9	114.9	NA	79.1	82.5	79.5	NA	78	72	76	69	NA	28.2	33.3	35.6	30	34	34	33	14	15	22	19	5.5	6.3	6.9	5.5	<0.88	<0.88
Barium, ug/L	P	1,147	2,000	NA	64.3	67.1	66.5	NA	70	70	66	74	NA	154	180	194	130	180	260	220	160	150	190	200	510	490	680	610	270	270
Beryllium, ug/L	NP*	0.036	4	NA	<0.012	<0.12	<0.089	NA	<0.27	<0.27	<0.27	<0.27	NA	0.012 J	<0.12	<0.089	<0.27	<0.54	<0.27	<0.27	<0.27	<0.54	<0.27	<0.27	<0.27	<1.1	<0.27	<0.27	<0.27	<0.27
Cadmium, ug/L	NP*	0.025	5	NA	0.020 J	<0.070	0.058 J	NA	<0.077	<0.039	0.044 J	<0.049	NA	0.021 J	<0.070	<0.033	<0.077	<0.039	<0.039	<0.049	<0.077	0.044 J	0.095 J	0.066 J	<0.077	<0.039	0.039 J	<0.049	<0.049	<0.049
Chromium, ug/L	P*	0.090	100	NA	0.25 J,B	<0.19	0.16 J	NA	<0.98	<0.98	<1.1	<1.1	NA	0.32 J,B	0.22 J	0.18 J	<0.98	<0.98	<1.1	<1.1	<0.98	<0.98	<1.1	<1.1	<0.98	<0.98	<1.1	<1.1	<1.1	<1.1
Cobalt, ug/L	P	3.87	6	NA	0.057 J	<0.15	0.074 J	NA	<0.091	<0.091	<0.091	<0.091	NA	4.9	0.82 J	0.68 J	1.3	0.52	0.57	0.33 J	0.65	0.36 J	0.67	0.5	0.41 J	0.32 J	0.23 J	0.19 J	<0.091	<0.091
Fluoride, mg/L	P	0.427	4	NA	0.17 J	0.16 J	<0.19	NA	0.37 J	<0.23	0.37 J	<0.23	NA	0.40	0.43	0.40	0.71	0.29 J	0.58	<0.23	1.1	0.25 J	0.57	<0.23	0.33 J	0.28 J	0.52	<0.23	<0.23	<0.23
Lead, ug/L	NP*	0.64	15	NA	0.25 J	0.27 J	0.45 J,B	NA	<0.27	<0.27	0.40 J	0.15 J	NA	0.045 J	<0.12	<0.13	<0.27	<0.27	<0.27	<0.11	0.54	<0.27	<0.27	<0.11	<0.27	0.31 J	<0.27	<0.11	<0.11	<0.11
Lithium, ug/L	NP*	7.7	40	NA	46.0	52.0	43.6	48.9	50	52	48	51	NA	<4.6	<4.6	<4.6	3.3 J	<5.4	2.4 J	<2.5	24	27	22	27	43	62	52	51	13	13
Mercury, ug/L	DQ	DQ	2	NA	<0.090	NA	<0.090	NA	<0.10	NA	0.13 J	<0.10	NA	<0.090	NA	<0.090	<0.10	NA	<0.10	<0.10	<0.10	NA	<0.10	<0.10	<0.10	NA	0.13 J	<0.10	<0.10	<0.10
Molybdenum, ug/L	NP	14.7	100	NA	140	140	145	135	110	120	120	110	NA	43.4	52.8	71.8	47	90	87	100	290	280	320	290	130	110	130	100	120	120
Selenium, ug/L	P*	0.28	50	NA	0.31 J	0.43 J	0.4 J	NA	<1.0	<1.0	<1.0	<1.0	NA	0.30 J	0.31 J	0.29 J	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thallium, ug/L	NP*	0.35	2	NA	<0.036	NA	<0.099	NA	<0.27	NA	<0.26	NA	NA	<0.036	NA	<0.099	<0.27	NA	<0.26	NA	<0.27	NA	<0.26	NA	<0.27	NA	<0.26	NA	<0.26	NA
Radium 226/228 Combined, pCI/L	P	3.36	5	NA	0.283	0.0726	0.334	NA	0.328	0.288	0.268	Pending	NA	0.218	0.96	1.05	0.42	0.596	0.296	Pending	0.875	0.438	0.543	Pending	0.987	1.70	1.81	Pending	1.5	Pending
Additional Parameter Collected for Selection of Remed																														
Lithium, dissolved,# ug/L	UPL or GPS not applicable			NA	NA	NA	NA	NA	NA	NA	NA	53.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	53.0	NA	NA
Iron, dissolved,# ug/L				NA	NA	NA	NA	NA	NA	NA	NA	<50.0	NA	NA	NA	NA	NA	NA	NA	11,000	NA	NA	NA	11,000	NA	NA	NA	14,000	NA	1,700
Iron, ug/L				NA	NA	NA	NA	NA	NA	NA	NA	<50.0	NA	NA	NA	NA	NA	NA	NA	12,000	NA	NA	NA	11,000	NA	NA	NA	15,000	NA	1,600
Magnesium, dissolved,#				NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA		NA	NA	NA		NA	NA	NA		NA	
Magnesium, ug/L				NA	NA	NA	NA	NA	NA	NA	NA	1,700	NA	NA	NA	NA	NA	NA	NA	18,000	NA	NA	NA	12,000	NA	NA	NA	21,000	NA	4,300
Manganese, dissolved,# ug/L				NA	NA	NA	NA	NA	NA	NA	NA	290	NA	NA	NA	NA	NA	NA	NA	3,400	NA	NA	NA	8,200	NA	NA	NA	6,300	NA	680
Manganese, ug/L				NA	NA	NA	NA	NA	NA	NA	NA	280	NA	NA	NA	NA	NA	NA	NA	3,200	NA	NA	NA	7,900	NA	NA	NA	6,100	NA	670
Molybdenum, dissolved,# ug/L				NA	NA	NA	NA	NA	NA	NA	NA	110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	300	NA	NA	NA	100	NA	120
Potassium, ug/L				NA	NA	NA	NA	NA	NA	NA	NA	35,000	NA	NA	NA	NA	NA	NA	NA	1,800	NA	NA	NA	11,000	NA	NA	NA	14,000	NA	12,000
Sodium, ug/L				NA	NA	NA	NA	NA	NA	NA	NA	84,000	NA	NA	NA	NA	NA	NA	NA	90,000	NA	NA	NA	73,000	NA	NA	NA	58,000	NA	####
Bicarbonate Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	NA	54.0	NA	NA	NA	NA	NA	NA	NA	190	NA	NA	NA	240	NA	NA	NA	380	NA	88.0
Carbonate Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	NA	89.0	NA	NA	NA	NA	NA	NA	NA	<3.8	NA	NA	NA	<3.80	NA	NA	NA	<3.80	NA	<1.9
Total Alkalinity, mg/L				NA	NA	NA	NA	NA	NA	NA	NA	140	NA	NA	NA	NA	NA	NA	NA	190	NA	NA	NA	240	NA	NA	NA	380	NA	88.0

4.4	Blue highlighted cell indicates the compliance well result exceeds the UPL (background) and the LOQ.
30.8	Yellow highlighted cell indicates the compliance well result exceeds the GPS.
17	Grayscale indicates Additional Parameters sampled for selection of remedy and evaluation of Monitored Natural Attenuation.

See page 5 for Notes and Abbreviations

Table 3. Groundwater Analytical Results Summary - Assessment Monitoring
Burlington Generating Station, Burlington, IA / SCS Engineers Project #25220066.00

Abbreviations:

UPL = Upper Prediction Limit
NA = Not Analyzed
mg/L = milligrams per liter
GPS = Groundwater Protection Standard
DQ = Double Quantification Rule (not detected in background)
NP = Nonparametric UPL (highest background value) with 1-of2- retesting
LOD = Limit of Detection
LOQ = Limit of Quantification
P = Parametric UPL with 1-of-2 retesting

J = Estimated concentration at or above the LOD and below the LOQ.

* = UPL is below the LOQ for background sampling. For compliance wells, only results confirmed above the LOQ are evaluated as potential SSIs above background.
** = UPL for arsenic is greater than the MCL and will be used as the GPS.
*% = Monitoring well is located near the MW-310 background well but more date is needed to confirm if this monitoring well is representative of background groundwater conditions.
# = Dissolved parameter samples collected for MNA data review

Notes:

1. An individual result above the UPL or GPS does not constitute a statistically significant increase (SSI) above background or statistically significant level above the GPS. See the accompanying letter text for identification of statistically significant results.
2. GPS is the United States Environmental Protection Agency (US EPA) Maximum Contamination Level (MCL), if established, or the value from 40 CFR 257.95(h)(2), or the background UPL if it is higher.
3. Interwell UPLs calculated based on results from background wells MW-310 and MW-311.

Created by:	NDK	Date:	5/1/2018
Last revision by:	NDK	Date:	11/15/2020
Checked by:	ACW	Date:	11/17/2020
Scientist or Proj Mgr QA/QC:	TK	Date:	11/19/2020

Table 4. Groundwater Field Parameters - CCR Program - Assessment Monitoring
Burlington Generating Station / SCS Project # 25219168.00
October 2017 - October 2020

Well	Sample Date	Field Temperature (deg C)	Field pH (Std. Units)	Oxygen, Dissolved (mg/L)	Field Specific Conductance (umhos/cm)	Oxidation-Reduction Potential (mV)	Turbidity (NTU)	Groundwater Elevation (feet)
MW-301	10/16/2017	13.8	7.58	0.12	1065	38	1.26	522.13
	5/9/2018	12.9	7.40	0.08	601	-167	4.23	525.51
	8/13/2018	16.8	7.91	0.35	1400	-145	5.78	520.19
	10/9/2018	17.2	7.34	0.24	892	-64	8.43	528.01
	3/12/2019	12.6	6.38	2.61	1055	-73	17.1	523.38
	4/3/2019	12.4	7.53	0.59	1213	-145	21.1	528.15
	10/10/2019	13.9	6.85	0.23	1063	-163	12.55	--
	6/3/2020	13.4	6.99	0.25	1167	37	20.15	523.94
	10/16/2020	13.7	7.07	0.09	1503	-188	3.41	519.26
MW-302	10/17/2017	13.9	8.72	0.09	1165	-49.7	2.04	522.20
	5/9/2018	13.0	8.19	1.0	1268	-217.2	2.25	525.81
	8/13/2018	14.9	9.32	0.15	1226	-237	3.75	519.87
	10/9/2018	15.2	7.89	0.3	1334	-198	6.48	528.08
	3/12/2019	12.2	6.94	2.68	792	-70.3	22.1	522.83
	4/3/2019	11.4	8.70	0.58	1164	-215.8	18.8	528.21
	10/10/2019	14.5	7.49	0.28	1249	-186.8	1.16	--
	6/3/2020	12.9	7.88	0.18	1245	36.7	25.27	523.98
	10/16/2020	12.9	7.87	0.08	1168	-237.1	0.07	518.94
MW-302A	9/9/2020	13.3	7.31	--	1013	-142	0.01	519.71
	10/16/2020	13.1	7.26	0.19	951	-175.3	3.82	518.79

Table 4. Groundwater Field Parameters - CCR Program - Assessment Monitoring
Burlington Generating Station / SCS Project # 25219168.00
October 2017 - October 2020

Well	Sample Date	Field Temperature (deg C)	Field pH (Std. Units)	Oxygen, Dissolved (mg/L)	Field Specific Conductance (umhos/cm)	Oxidation-Reduction Potential (mV)	Turbidity (NTU)	Groundwater Elevation (feet)
MW-303	10/17/2017	14.5	8.59	0.13	613	21.3	2.79	522.23
	5/9/2018	13.8	7.51	0.11	536	-165.5	0.97	525.80
	8/13/2018	16.8	8.03	0.24	748	-153	14.26	519.78
	10/10/2018	15.6	7.10	1.0	774	-132	17.3	528.78
	3/12/2019	13.6	6.46	2.38	549	-68.1	19.4	522.74
	4/3/2019	12.6	7.79	0.67	711	-122.8	18.2	528.22
	10/10/2019	14.9	7.13	0.26	767	-161	5.36	--
	6/3/2020	14.8	7.12	0.18	934	58.1	16.03	523.97
	10/16/2020	13.7	7.19	0.12	902	-185.6	2.03	518.78
MW-304	10/17/2017	15.1	9.52	0.1	756	5.9	1.89	522.32
	5/9/2018	13.5	8.51	1.4	906	-273	2.84	525.85
	8/13/2018	18.1	7.60	0.09	836	-202	4.26	519.81
	10/10/2018	17.4	9.01	0.23	780	-100.2	1.36	528.82
	3/12/2019	13.9	6.94	2.11	460	-73.8	9.28	522.80
	4/3/2019	13.0	8.56	0.39	658	-216.7	6.22	528.27
	10/10/2019	15.6	7.17	0.28	934	-157.5	1.18	--
	6/3/2020	14.6	7.23	0.15	1087	52.4	18.18	524.02
	10/15/2020	14.7	8.46	0.08	1062	-282.6	0.02	518.69
MW-305	10/16/2017	15.1	7.78	0.14	759	44.9	0.71	522.48
	5/9/2018	15.2	7.72	1.4	733	-146.8	0.64	526.06
	8/13/2018	16.3	7.81	0.35	901	-134	3.85	520.29
	10/10/2018	16.2	7.29	0.2	846	-140	4.94	528.97
	4/3/2019	14.5	7.80	0.59	733	-133.5	3.88	528.36
	10/11/2019	14.3	7.36	0.2	795	-132.9	3.02	--
	6/3/2020	15.9	7.12	0.14	972	39.8	13.46	524.12
	10/15/2020	14.6	7.23	0.37	987	-175	0.02	519.00

Table 4. Groundwater Field Parameters - CCR Program - Assessment Monitoring
Burlington Generating Station / SCS Project # 25219168.00
October 2017 - October 2020

Well	Sample Date	Field Temperature (deg C)	Field pH (Std. Units)	Oxygen, Dissolved (mg/L)	Field Specific Conductance (umhos/cm)	Oxidation-Reduction Potential (mV)	Turbidity (NTU)	Groundwater Elevation (feet)
MW-306	10/16/2017	14.8	10.66	0.37	448	286.2	0.35	522.72
	5/9/2018	14.7	6.80	0.05	354	-104.3	0.71	526.00
	8/14/2018	15.9	10.33	0.3	447	-265	2.88	520.14
	10/10/2018	17.3	6.04	0.38	478	58.1	2.67	528.95
	3/11/2019	14.3	6.27	0.8	343	-88.9	0.56	523.21
	4/3/2019	13.4	6.69	0.69	4711	-92.8	0.81	528.40
	10/11/2019	14.3	10.53	0.21	473	-165.1	1.84	--
	6/4/2020	14.4	10.48	0.16	482	59	15.96	524.45
	10/15/2020	14.1	10.00	0.11	454	-273.7	0.02	519.05
MW-307	10/16/2017	14.7	10.46	0.18	486	-78.9	0.32	522.55
	5/9/2018	14.4	10.30	1.1	500	-168.6	1.87	526.06
	8/14/2018	15.6	10.12	0.49	512	-221	5.09	520.46
	10/10/2018	15.6	9.88	0.22	497	-87.3	1.85	529.08
	3/11/2019	14.4	9.71	1.07	367	-78.3	1.05	523.49
	4/3/2019	13.6	10.39	0.68	500	-167.8	3.1	528.63
	10/11/2019	14.4	10.14	0.24	536	-126.3	3.23	--
	6/4/2020	14.8	10.03	0.3	586	60.2	14.33	524.62
	10/15/2020	14.0	10.05	0.11	565	-269.7	0.02	519.33
MW-307A	9/9/2020	14.4	7.83	--	585	-154.2	0	519.97
	10/14/2020	14.6	7.80	0.18	554	-189.9	2.96	519.00

Table 4. Groundwater Field Parameters - CCR Program - Assessment Monitoring
Burlington Generating Station / SCS Project # 25219168.00
October 2017 - October 2020

Well	Sample Date	Field Temperature (deg C)	Field pH (Std. Units)	Oxygen, Dissolved (mg/L)	Field Specific Conductance (umhos/cm)	Oxidation-Reduction Potential (mV)	Turbidity (NTU)	Groundwater Elevation (feet)
MW-308	10/17/2017	14.6	9.75	0.09	689	-109.4	0.6	522.46
	5/8/2018	14.4	9.75	1.5	698	-158.2	1.26	525.62
	8/13/2018	15.4	9.86	0.11	710	-238	4.63	520.22
	10/10/2018	15.3	9.82	0.2	709	-201	1.35	528.98
	3/12/2019	14.1	7.72	2.57	500	-60.7	1.68	523.13
	4/3/2019	14.0	9.97	1.16	681	-142.3	1.66	528.39
	10/10/2019	14.6	9.42	0.21	671	-82.6	2.93	--
	6/4/2020	15.4	9.65	0.23	713	28	13.38	524.10
	10/14/2020	14.7	9.70	0.1	682	-264.6	0.15	519.02
MW-309	10/17/2017	14.6	8.50	0.08	1058	-31	3.08	522.67
	5/8/2018	13.5	7.25	0.05	813	-139.2	6.49	525.54
	8/14/2018	14.2	7.39	0.14	1093	-143	12.67	520.22
	10/10/2018	15.7	7.46	0.18	1038	-53.5	34.45	528.93
	4/4/2019	12.6	7.45	0.51	997	-99.4	20.1	528.40
	10/11/2019	13.7	7.19	0.21	1040	-165.6	8.93	--
	6/3/2020	14.8	7.09	0.23	1086	37	18.88	524.06
	10/14/2020	14.3	7.61	0.14	851	-208.4	18.9	519.28
MW-310	10/16/2017	16.6	7.92	0.16	791	-63.6	2.86	525.49
	5/8/2018	11.1	7.46	0.14	595	-198.8	12.81	525.79
	8/14/2018	15.0	7.44	0.05	840	-194	3.11	523.69
	10/10/2018	17.0	7.20	0.1	938	-166	0	529.00
	4/4/2019	10.8	7.84	1.12	1034	-175.8	16.7	528.62
	10/11/2019	15.9	6.95	0.28	961	-189.7	5.23	--
	6/2/2020	12.8	7.30	0.13	881	38.6	17.82	525.36
	10/14/2020	16.4	7.34	0.08	711	-223.6	3.79	523.81

Table 4. Groundwater Field Parameters - CCR Program - Assessment Monitoring
Burlington Generating Station / SCS Project # 25219168.00
October 2017 - October 2020

Well	Sample Date	Field Temperature (deg C)	Field pH (Std. Units)	Oxygen, Dissolved (mg/L)	Field Specific Conductance (umhos/cm)	Oxidation-Reduction Potential (mV)	Turbidity (NTU)	Groundwater Elevation (feet)
MW-310A	9/9/2020	14.2	7.33	--	1026	145.3	714.3	509.16
	10/16/2020	--	--	--	--	--	--	489.84
MW-311	10/16/2017	14.7	8.27	0.25	972	308.3	2.19	523.44
	5/8/2018	11.5	7.26	1.6	1282	-143.3	1.48	525.08
	8/14/2018	14.8	7.33	0.12	1177	-158	12.3	521.06
	10/10/2018	16.4	7.49	0.45	1003	-62.2	17.8	528.49
	4/4/2019	11.4	7.64	0.78	1422	145.8	10.8	528.20
	10/11/2019	14.2	7.07	0.3	1088	-163.4	13.4	--
	6/2/2020	12.3	7.10	0.16	1464	-1.1	17.95	524.05
	10/14/2020	14.5	7.41	0.1	1041	-194	2.36	520.59
MW-312	6/6/2019	14.4	6.99	0.12	783	-146.4	2.86	--
	10/10/2019	15.6	7.19	8.75	785	-163.8	2.56	--
	6/3/2020	14.7	7.13	0.17	878	53.3	21.16	524.05
	10/15/2020	15.1	7.37	0.13	854	-203.1	0.02	518.68
MW-313	6/6/2019	14.9	6.94	0.07	1059	-141.6	7.23	--
	10/10/2019	16.0	7.06	0.37	1007	-163.4	11.03	--
	6/3/2020	17.2	7.03	0.29	1099	50.9	50.81	524.02
	10/15/2020	15.3	7.16	0.14	999	-183.3	14.3	518.70
MW-313A	9/9/2020	15.3	7.60	--	1243	-164.4	0	515.36
	10/15/2020	14.8	7.64	0.1	1133	-190.1	0.02	518.61

Table 5. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25219168.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill	Alternative #6 Consolidate and Cap with Chemical Amendment	Alternative #7 Consolidate and Cap with Groundwater Collection	Alternative #8 Consolidate and Cap with Barrier Wall
CORRECTIVE ACTION ASSESSMENT - 40 CFR 257.97(b)								
257.97(b)(1) Is remedy protective of human health and the environment?	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
257.97(b)(2) Can the remedy attain the groundwater protection standard?	Unlikely	Yes	Yes	Yes	Yes	Yes	Yes	Yes
257.97(b)(3) Can the remedy control the source(s) of releases so as to reduce or eliminate, to the maximum extent feasible, further releases of constituents in appendix IV to this part into the environment?	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
257.97(b)(4) Can the remedy remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible?	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR
257.97(b)(5) Can the remedy comply with standards for management of wastes as specified in §257.98(d)?	Not Applicable	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LONG- AND SHORT-TERM EFFECTIVENESS - 40 CFR 257.97(c)(1)								
257.97(c)(1)(i) Magnitude of reduction of existing risks	No reduction of existing risk	Existing risk reduced by achieving GPS	Same as Alternative #2	Same as Alternative #2	Same as Alternative #2	Similar to Alternative #2. Long-term risk may be reduced with additional source control and in-situ stabilization/fixation of CCR that may be in contact with groundwater.	Similar to Alternative #2. Groundwater extraction and treatment presents an additional risk and potential exposure pathways via surface release or disruption of treatment processes.	Similar to Alternative #2. Long-term risk may be reduced with additional containment offered by barrier wall.
257.97(c)(1)(ii) Magnitude of residual risks in terms of likelihood of further releases due to CCR remaining following implementation of a remedy	No reduction of existing risk. Residual risk is limited for all alternatives due to limited extent of impacts and lack of receptors.	Magnitude of residual risk of further releases is lower than current conditions due to final cover eliminating infiltration through CCR; Residual risk is limited for all alternatives due to limited extent of impacts and lack of receptors	Same as Alternative #2 with potential further reduction in release risk due to CCR material footprint; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts	Same as Alternative #3 with potential further reduction in release risk due to composite liner and cover; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts	Same as Alternative #3 with potential further reduction in release risk due to removal of CCR from site; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts	Same as Alternative #2 with potential further reduction in release risk due to CCR material footprint; Residual risk is further reduced by way of chemical / physical alteration of the source of impacts. However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts.	Same as Alternative #2 with potential further reduction in release risk due to CCR material footprint; Residual risk is potentially reduced by way of the ability to respond to potential future/ongoing releases from CCR that might be in contact with groundwater following closure. However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts.	Same as Alternative #2 with potential further reduction in release risk due to CCR material footprint; Residual risk of source material in contact with groundwater is further reduced by the containment of groundwater impacts provided by barrier walls; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts.
257.97(c)(1)(iii) The type and degree of long-term management required, including monitoring, operation, and maintenance	Not Applicable	30-year post-closure groundwater monitoring; Groundwater monitoring network maintenance and as-needed repair/replacement; Final cover maintenance (e.g., mowing and as-needed repair); Periodic final cover inspections; Additional corrective action as required based on post-closure groundwater monitoring	Same as Alternative #2	Same as Alternative #2	No on-site long-term management required; Limited on-site post-closure groundwater monitoring until GPS are achieved; Receiving disposal facility will have same/similar long-term monitoring, operation, and maintenance requirements as Alternative #2	Same as Alternative #2	Same as Alternative #2 with additional effort for groundwater pump operation and maintenance (O&M), groundwater treatment system O&M, and treatment system discharge monitoring/reporting.	Same as Alternative #2 with additional monitoring of wall performance.

Table 5. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25219168.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill	Alternative #6 Consolidate and Cap with Chemical Amendment	Alternative #7 Consolidate and Cap with Groundwater Collection	Alternative #8 Consolidate and Cap with Barrier Wall
LONG- AND SHORT-TERM EFFECTIVENESS - 40 CFR 257.97(c)(1) (continued)								
257.97(c)(1)(iv) Short-term risks - Implementation								
Excavation	None	Limited risk to community and environment due to limited amount of excavation (<100K cy) required to establish final cover subgrades and no off-site excavation	Same as Alternative #2 with increased risk to environment due to increased excavation volumes (>100K cy, <300K cy) required for consolidation	Same as Alternative #3 with increased risk to environment due to increased excavation volumes (>1M cy) and temporary CCR storage during disposal site construction required for removal and on-site re-disposal	Same as Alternative #4 with reduced risk to environment from excavation due to limited on-site storage	Similar to Alternative #3 with some increased potential risk due to exposure during the application of the chemical amendment.	Similar to Alternative #3 with some increased construction risk due to drilling, trenching, and excavation for groundwater pumping and treatment system construction.	Similar to Alternative #3 with some increased construction risk due to excavation or installation of the barrier wall.
Transportation	None	No risk to community or environment from off-site CCR transportation; Typical risk due to construction traffic delivering final cover materials to site	Same as Alternative #2 with reduced risk from construction traffic due to reduced final cover material requirements (smaller cap footprint)	Same as Alternative #2 with increased risk from construction traffic due to increased material import requirements (liner and cap construction required)	Highest level of community and environmental risk due to CCR volume export (>1M cy)	Similar to Alternative #3 with increased risk from importing chemical material for stabilization/treatment.	Similar to Alternative #3 with increased risk from importing groundwater pumping and treatment system materials.	Similar to Alternative #3 with increased risk from importing barrier wall system materials.
Re-Disposal	None	Limited risk to community and environment due to limited volume of CCR re-disposal (<100K cy)	Same as Alternative #2 with increased risk to environment due to increased excavation volumes (>100K cy, <300K cy) required for consolidation	Same as Alternative #3 with increased risk to environment due to increased excavation volumes (>1M cy) and temporary CCR storage during disposal site construction required for removal and on-site re-disposal	Same as Alternative #4 with increased risk to community and environment due to re-disposal of large CCR volume (>1M cy) at another facility; Re-disposal risks are managed by the receiving disposal facility	Similar to Alternative #3 with some increased potential risk due to exposure during the application of the chemical amendment.	Same as Alternative #3	Same as Alternative #3
257.97(c)(1)(v) Time until full protection is achieved	Unknown	To be evaluated further during remedy selection. Closure and capping anticipated by end of 2022. Groundwater protection timeframe to reach GPS potentially 2 to 10 years following closure construction, achievable within 30-year post-	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential for decrease in time to reach GPS due to consolidation of CCR.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential decrease in time to reach GPS due to source isolation within liner/cover system.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential decrease in time to reach GPS due to impounded CCR source removal.	Similar to Alternative #2. Potential for reduction in time to reach GPS due to chemical/physical stability of CCR.	Similar to Alternative #2. Potential decrease in time to reach GPS at property line from implementation of groundwater pumping.	Similar to Alternative #2. Potential decrease in time to reach GPS upon implementation of barrier wall.
257.97(c)(1)(vi) Potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, re-disposal, or containment	No change in potential exposure	Potential for exposure is low. Remaining waste is capped.	Same as Alternative #2	Same as Alternative #2	No potential for on-site exposure to remaining waste since no waste remains on site; Risk of potential exposure is transferred to receiving disposal facility and is likely similar to Alternative #2	Same as Alternative #2	Similar to Alternative #2 with potential for secondary impacts from releases of extracted groundwater or disruption in treatment.	Same as Alternative #2
257.97(c)(1)(vii) Long-term reliability of the engineering and institutional controls	Not Applicable	Long-term reliability of cap is good; Significant industry experience with methods/ controls; Capping is common practice/industry standard for closure in place for remediation and solid waste management	Same as Alternative #2 with potentially increased reliability due to smaller footprint and reduced maintenance	Same as Alternative #3	Success of remedy at BGS does not rely on long-term reliability of engineering or institutional controls; Overall success relies on reliability of the engineering and institutional controls at the receiving facility.	Same as Alternative #3.	Same as Alternative #3. Remedy relies upon active equipment that will require additional operations and maintenance.	Same as Alternative #3. Remedy relies on continued hydraulic conductivity of the selected barrier. Breaches or short circuiting can develop and must be monitored.
257.97(c)(1)(viii) Potential need for replacement of the remedy	Not Applicable	Limited potential for remedy replacement if maintained; Some potential for remedy enhancement due to residual groundwater impacts following source control	Same as Alternative #2 with reduced potential need for remedy enhancement with consolidated/smaller closure area footprint	Same as Alternative #2 with further reduction in potential need for remedy enhancement composite with liner	No on-site potential for remedy replacement; Limited potential for remedy enhancement due to residual groundwater impacts following source control	Similar to Alternative #3, with further reduction in potential need for remedy enhancement due to stabilized/solidified CCR material.	Similar to Alternative #2, with reduced potential of remedy replacement, but added expectation for pump, conveyance system and treatment system replacement.	Similar to Alternative #2, with reduced potential of remedy replacement, but added expectation for potential replenishment of consumptive barrier product.

Table 5. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25219168.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill	Alternative #6 Consolidate and Cap with Chemical Amendment	Alternative #7 Consolidate and Cap with Groundwater Collection	Alternative #8 Consolidate and Cap with Barrier Wall
SOURCE CONTROL TO MITIGATE FUTURE RELEASES - 40 CFR 257.97(c)(2)								
257.97(c)(2)(i) The extent to which containment practices will reduce further releases	No reduction in further releases	Cap will reduce further releases by minimizing infiltration through CCR	Same as Alternative #2 with further reduction due to consolidated/smaller closure footprint	Same as Alternative #3 with further reduction due to composite liner and 5-foot groundwater separation required by CCR Rule	Removal of CCR prevents further releases at BGS; Receiving disposal site risk similar to Alternative #3	Similar to Alternative #3 with further reduction due to lower mobility of contaminants in residual source material as a result of chemical amendment.	Similar to Alternative #3 with the added ability to contain or restore groundwater impacts if MNA mechanisms are not active or site attenuation capacity is not adequate.	Similar to Alternative #3 with the added ability to contain groundwater impacts if MNA mechanisms are not active or site attenuation capacity is not adequate.
257.97(c)(2)(ii) The extent to which treatment technologies may be used	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative relies on the identification and availability of a suitable chemical amendment. Implementation of and contact with physical/chemical stabilizing agent will require specialized field implementation methods and health and safety measures.	This alternative relies on conventional pump and treat remediation.	Alternative relies on the identification and availability of a suitable barrier wall technology (e.g., permeable reactive barrier material or slurry wall). Implementation of and contact with barrier wall materials will require specialized field implementation methods and health and safety measures.
IMPLEMENTATION - 40 CFR 257.97(c)(3)								
257.97(c)(3)(i) Degree of difficulty associated with constructing the technology	Not Applicable	Low complexity construction; Potentially lowest level of dewatering effort - dewatering required for cap installation only	Low complexity construction; Moderate degree of logistical complexity; Moderate to low level of dewatering effort - dewatering required for material excavation/placement and capping	Moderate complexity construction due to composite liner and cover; High degree of logistical complexity due to excavation and on-site storage of >1M cy of CCR while new lined disposal area is constructed; Moderate to high level of dewatering effort - dewatering required for excavation of full CCR volume	Low complexity construction; High degree of logistical complexity including the excavation and off-site transport of >1M cy of CCR and permitting/development of off-site disposal facility airspace; Moderate to high level of dewatering effort - dewatering required for excavation of full CCR volume	Moderate complexity construction due to the equipment required to apply the selected amendment; requirements to ensure consistent contact and dosing of amendment; Medium degree of logistical complexity involving the import of specialty chemicals; Moderate to low level of dewatering effort - dewatering required for material excavation/placement and capping	Low complexity construction; Moderate degree of logistical complexity; Moderate to low level of dewatering effort - dewatering required for material excavation/placement and capping. Moderate complexity construction for the installation of extraction wells and conveyance to a site-specific groundwater treatment plant.	High complexity construction; Barrier walls require specialty installation equipment and knowledge. Highly specialized and experience contractors required to achieve proper installation. Moderate degree of logistical complexity; Moderate to low level of dewatering effort - dewatering required for material excavation/placement and capping.
257.97(c)(3)(ii) Expected operational reliability of the technologies	Not Applicable	High reliability based on historic use of capping as corrective measure	Same as Alternative #2	Same as Alternative #2	Success at BGS does not rely on operational reliability of technologies; Overall success relies on off-site disposal facility, which is likely same/similar to Alternative #2	Similar to Alternative #2; however, success at BGS relies on the successful application of specialty chemicals.	Similar to Alternative #2; however, success of this remedy relies on the successful operation of a site-specific groundwater treatment plant.	Similar to Alternative #2; however, success this remedy relies on continued hydraulic conductivity of the selected barrier. Breaches or short circuiting can develop and must be monitored.
IMPLEMENTATION - 40 CFR 257.97(c)(3) (continued)								
257.97(c)(3)(iii) Need to coordinate with and obtain necessary approvals and permits from other agencies	Not Applicable	Need is moderate in comparison to other alternatives State Closure Permit required; Federal/State/Local Floodplain permitting required; State and local erosion control/construction stormwater management permits required; Federal/State wetland permitting potentially required	Need is lowest in comparison to other alternatives; State Closure Permit required; State and local erosion control/construction stormwater management permits required; Federal/State/Local Floodplain permitting likely required	Need is high in comparison to other alternatives State Closure Permit required; State Landfill Permit may be required; Federal/State/Local Floodplain permitting likely required; State and local erosion control/construction stormwater management permits required; Federal/State wetland permitting likely required	Need is highest in comparison to other alternatives; State Closure Permit required; State and local erosion control/construction stormwater management permits required; Approval of off-site disposal site owner required; May require State solid waste comprehensive planning approval; Federal/State/Local Floodplain permitting likely required; Federal/State wetland permitting likely required; Local road use permits likely required	Need is moderate in comparison to other alternatives; State Closure Permit required; Underground Injection Control Permit may be required if chemical materials placed within groundwater. State and local erosion control/construction stormwater management permits required; Federal/State/Local Floodplain permitting likely required.	Need is moderate in comparison to other alternatives; State Closure Permit required; Well permitting for extraction well installation; NPDES Permit for groundwater treatment and discharge; State and local erosion control/construction stormwater management permits required; Federal/State/Local Floodplain permitting likely required.	Need is moderate in comparison to other alternatives; State Closure Permit required; Well permitting for barrier wall monitoring; Federal/State/Local Floodplain permitting required; State and local erosion control/construction stormwater management permits required; Federal/State wetland permitting potentially required
257.97(c)(3)(iv) Availability of necessary equipment and specialists	Not Applicable	Necessary equipment and specialists are highly available; Highest level of demand for cap construction material	Same as Alternative #2; Lowest level of demand for cap construction material	Same as Alternative #2; Moderate level of demand for liner and cap construction material	Availability of necessary equipment to develop necessary off-site disposal facility airspace and transport >1M cy of CCR to new disposal facility will be a limiting factor in the schedule for executing this alternative; No liner or cover material demands for on-site implementation of remedy	Similar to Alternative #3; Moderate level of demand for liner and cap construction material. Specialized mixing equipment likely required to apply chemical amendment and achieve required dosing.	Similar to Alternative #3; Moderate level of demand for liner and cap construction material. A site-specific, trained employee will be required to operate the groundwater treatment system.	Similar to Alternative #3; Moderate level of demand for liner and cap construction material; Availability of the necessary specialized equipment and extensive experience required for barrier installation is potentially low or in high demand.
257.97(c)(3)(v) Available capacity and location of needed treatment, storage, and disposal services	Not Applicable	Capacity and location of treatment, storage, and disposal services is not a factor for this alternative	Capacity and location of treatment, storage, and disposal services is unlikely to be a factor for this alternative	Available temporary on-site storage capacity for >1M cy of CCR while composite liner is constructed is significant limiting factor	off-site disposal capacity, facility logistical capacity, or the time required to develop the necessary off-site disposal and logistical capacity is a significant limiting factor.	Capacity and location of treatment, storage, and disposal services is unlikely to be a factor for this alternative	Capacity and location of treatment, storage, and disposal services is unlikely to be a factor for this alternative	Capacity and location of treatment, storage, and disposal services is unlikely to be a factor for this alternative
COMMUNITY ACCEPTANCE - 40 CFR 257.97(c)(4)								
257.97(c)(4) The degree to which community concerns are addressed by a potential remedy (Anticipated)	Not Applicable	No comments were received during the public meeting held on October 14, 2020. Assume all alternatives are acceptable to interested/affected parties.	No comments were received during the public meeting held on October 14, 2020. Assume all alternatives are acceptable to interested/affected parties.	No comments were received during the public meeting held on October 14, 2020. Assume all alternatives are acceptable to interested/affected parties.	No comments were received during the public meeting held on October 14, 2020. Assume all alternatives are acceptable to interested/affected parties.	To be determined. Alternative added after public meeting held on October 14, 2020.	To be determined. Alternative added after public meeting held on October 14, 2020.	To be determined. Alternative added after public meeting held on October 14, 2020.

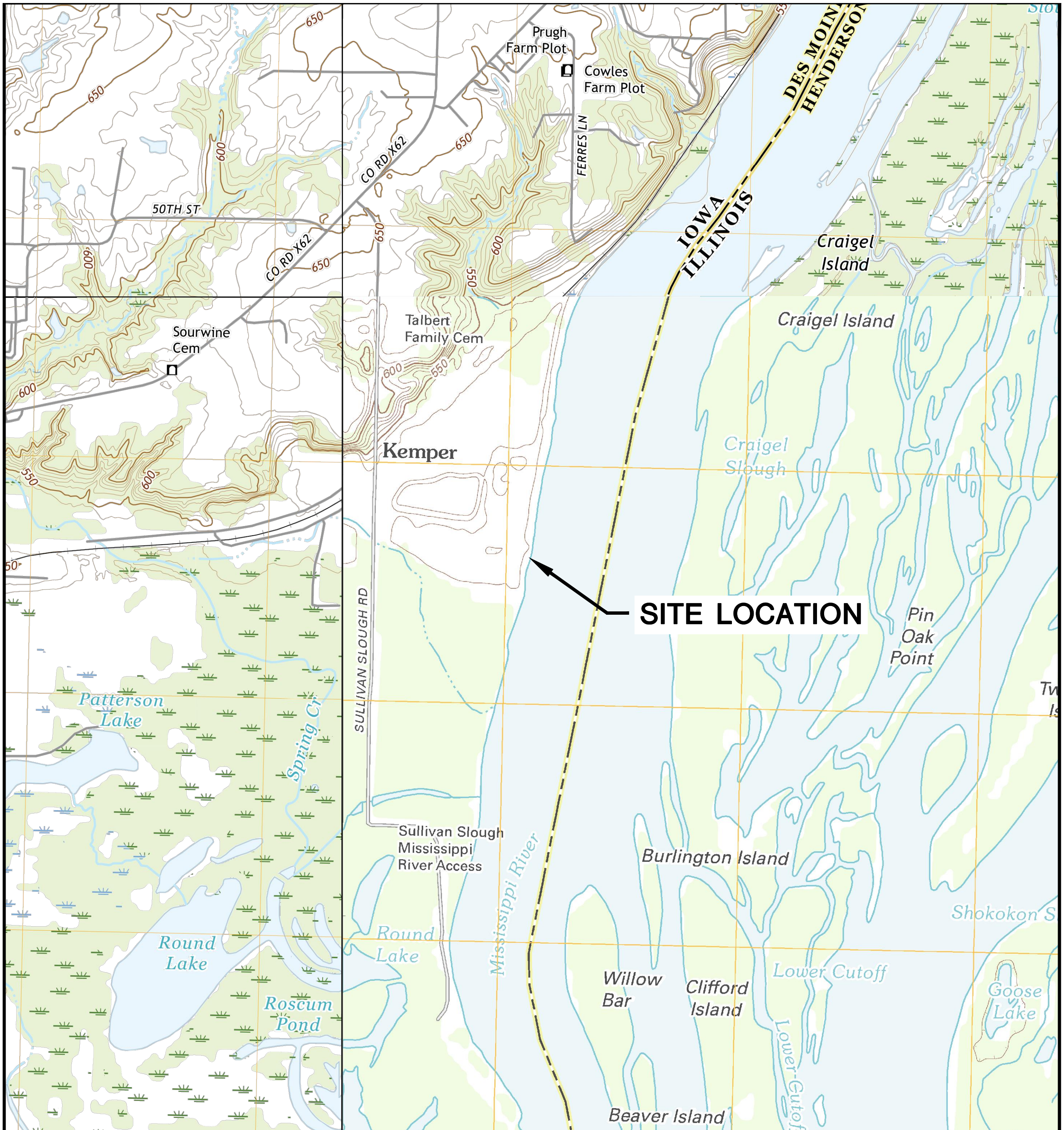
NOTES:

1) Alternatives #1 through #5 were developed and submitted within the Assessment of Corrective Measures Report (ACM), dated September 2019
2) Alternatives #6 through #8 were added in November 2020 as part of Addendum #1 to the September 2020 ACM Report

Created by: LAB/SK Date: 6/20/2019
Last revision by: SKK Date: 11/18/2020
Checked by: EJN Date: 11/19/2020

I:\25219168.00\Deliverables\ACM Addendum\Tables\[Table 5_Evaluation of Assessment of Corrective Measure_BGS.xlsx]BGS_Evaluation Matrix

Figures



LOMAX QUADRANGLE

IOWA–ILLINOIS

7.5 MINUTE SERIES (TOPOGRAPHIC)

2012

SCALE: 1" = 2,000'

CLIENT	SITE	
ALLIANT ENERGY 4902 N. BILTMORE LANE, #1000 MADISON, WI 53718	ALLIANT ENERGY BURLINGTON GENERATING STATION BURLINGTON, IOWA	SITE LOCATION MAP

				ENGINEER	FIGURE
PROJECT NO.	25219066.00	DRAWN BY:	AHB	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	1
DRAWN:	05/29/15	CHECKED BY:	KAK		
REVISED:	06/19/19	APPROVED BY:	TK 09/10/19		

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LEGEND

- EXISTING CCR RULE MONITORING WELL
- EXISTING CCR RULE PIEZOMETER
- CCR UNITS

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW-301, MW-302, AND MW-309 THROUGH MW-311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
4. 2018 AERIAL PHOTOGRAPH SOURCES: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA FSA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY.

N

300 0 300

SCALE: 1" = 300'

PROJECT NO.	25220081.00	DRAWN BY:	RJG
DRAWN:	11/14/2019	CHECKED BY:	MDB/EJN
REVISED:	10/16/2020	APPROVED BY:	TK

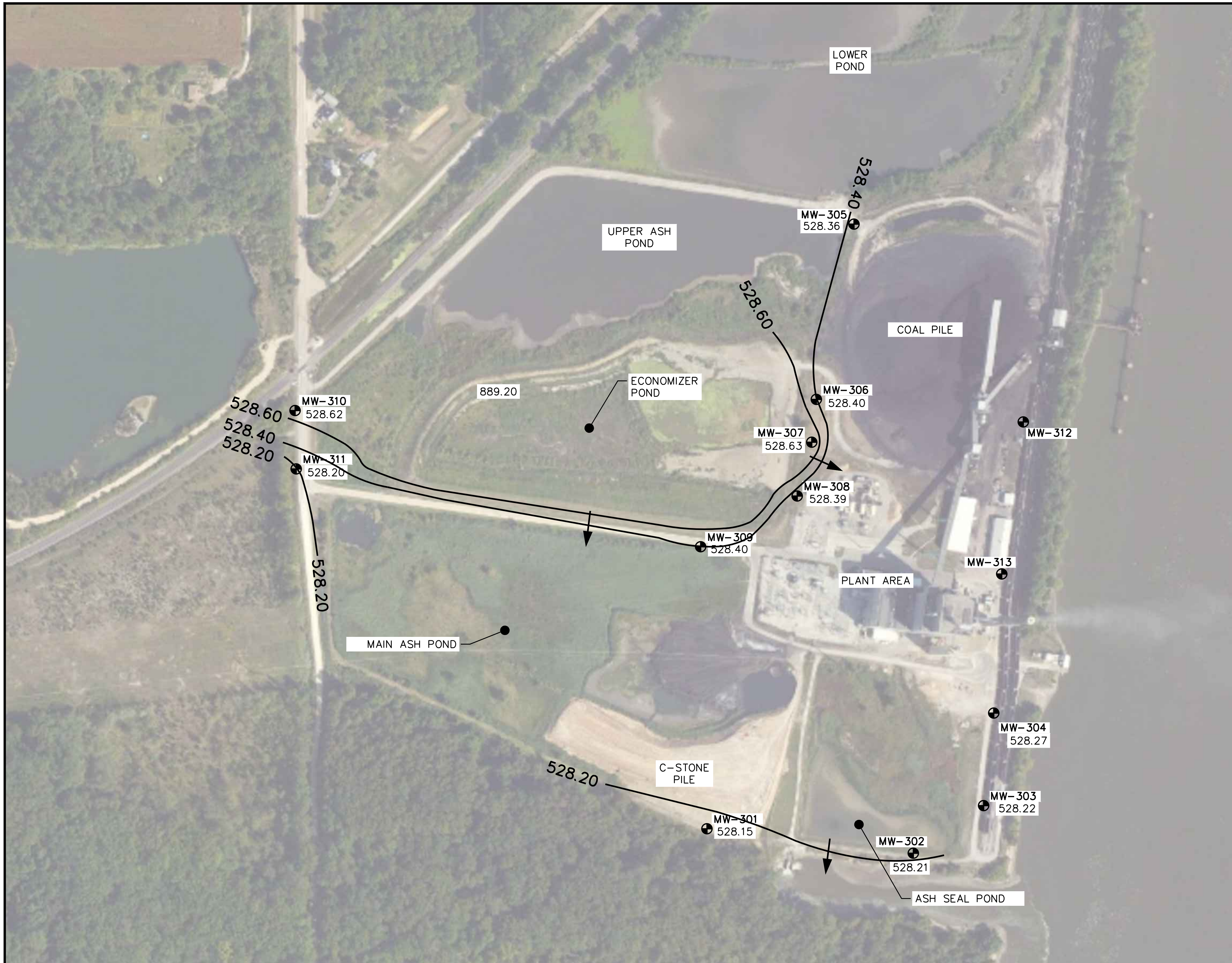
ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY
4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

SITE PLAN AND MONITORING WELL LOCATIONS

FIGURE 2



LEGEND

- EXISTING MONITORING WELL LOCATION
- WATER TABLE ELEVATION CONTOUR
- APPROXIMATE FLOW DIRECTION

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW301, MW302, AND MW309-MW311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-301 THROUGH MW-311 WERE SURVEYED BY FRENCH-RENEKER ASSOCIATES OF FRANKLIN, IA ON MARCH 16, 2016.
4. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
5. WATER TABLE ELEVATION ESTIMATED BASED ON MONITORING WELLS SCREENED BELOW THE WATER TABLE IN THE SAND UNIT.

PROJECT NO.	25219066.00	DRAWN BY:	BSS/LEC
DRAWN:	06/18/19	CHECKED BY:	NK
REVISED:	07/17/19	APPROVED BY:	TK 09/10/19

ENGINEER: SCS ENGINEERS, 2830 DAIRY DRIVE MADISON, WI 53718-6751, PHONE: (608) 224-2830

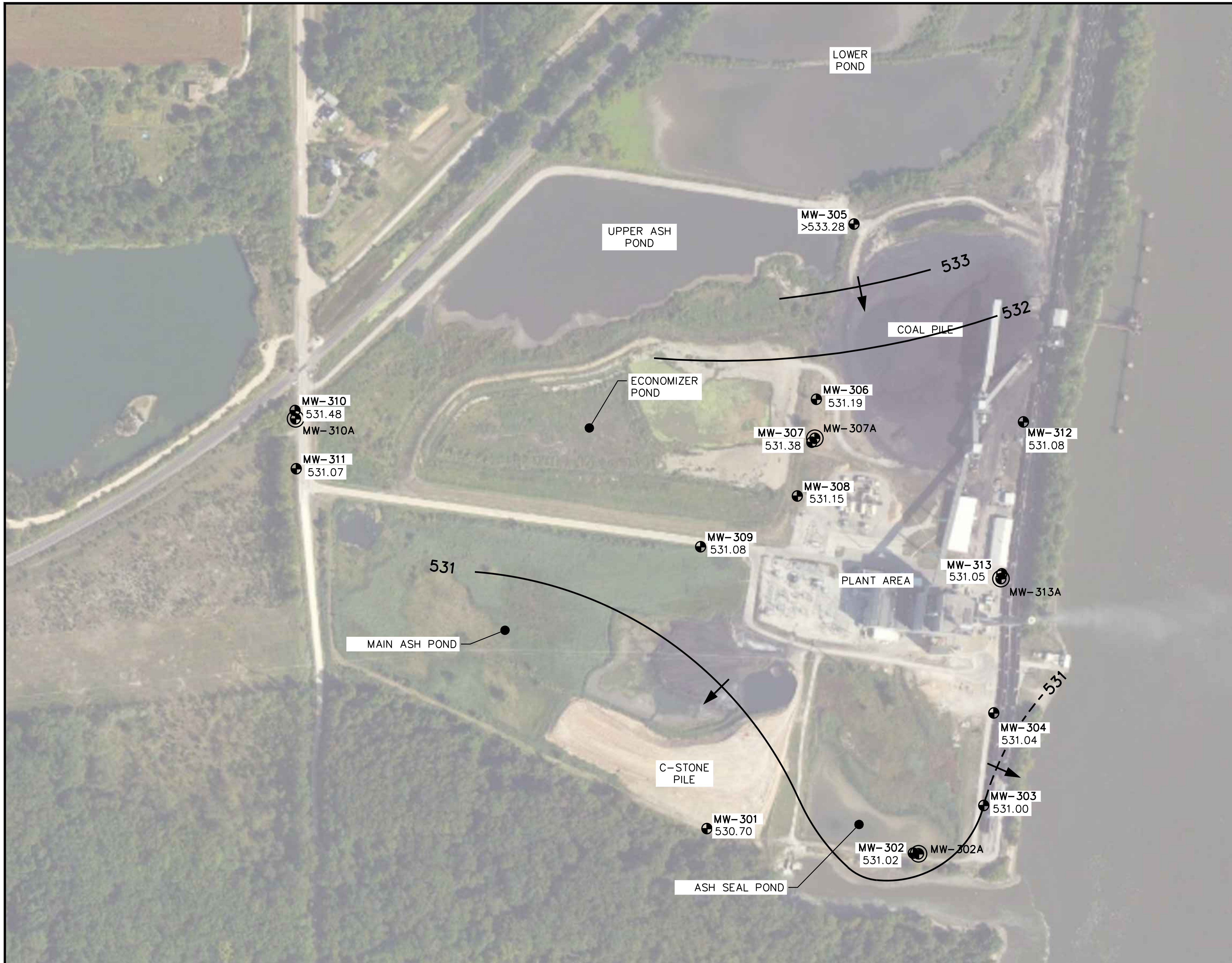
CLIENT: ALLIANT ENERGY, 4902 N. BILTMORE LANE, #1000, MADISON, WI 53718

SITE: ALLIANT ENERGY, BURLINGTON GENERATING STATION, BURLINGTON, IOWA

POTENTIOMETRIC SURFACE MAP
APRIL 3, 2019

FIGURE 3

I:\25219066.00\Drawings\WTBL Map.dwg, 11/19/2020 5:27:21 PM



LEGEND

- MONITORING WELL
- DEEP PIEZOMETER
- WATER TABLE ELEVATION CONTOUR (DASHED WHERE INFERRED)
- APPROXIMATE FLOW DIRECTION

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW301, MW302, AND MW309-MW311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-301 THROUGH MW-311 WERE SURVEYED BY FRENCH-RENEKER ASSOCIATES OF FRANKLIN, IA ON MARCH 16, 2016.
4. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
5. DEEP PIEZOMETERS MW-302A, MW-307A, MW-310A, AND MW-313A WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN JUNE-JULY 2020.
6. GROUNDWATER ELEVATION ESTIMATED BASED ON MONITORING WELLS SCREENED BELOW THE POTENTIOMETRIC SURFACE IN THE SAND UNIT.

N

300 0 300

SCALE: 1" = 300'

PROJECT NO.	252191680	DRAWN BY:	BSS/KP
DRAWN:	09/18/2020	CHECKED BY:	MDB
REVISED:	09/24/2020	APPROVED BY:	TK 10/21/20

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY
4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

HIGH POTENTIOMETRIC SURFACE MAP
JUNE 6, 2019

FIGURE 4

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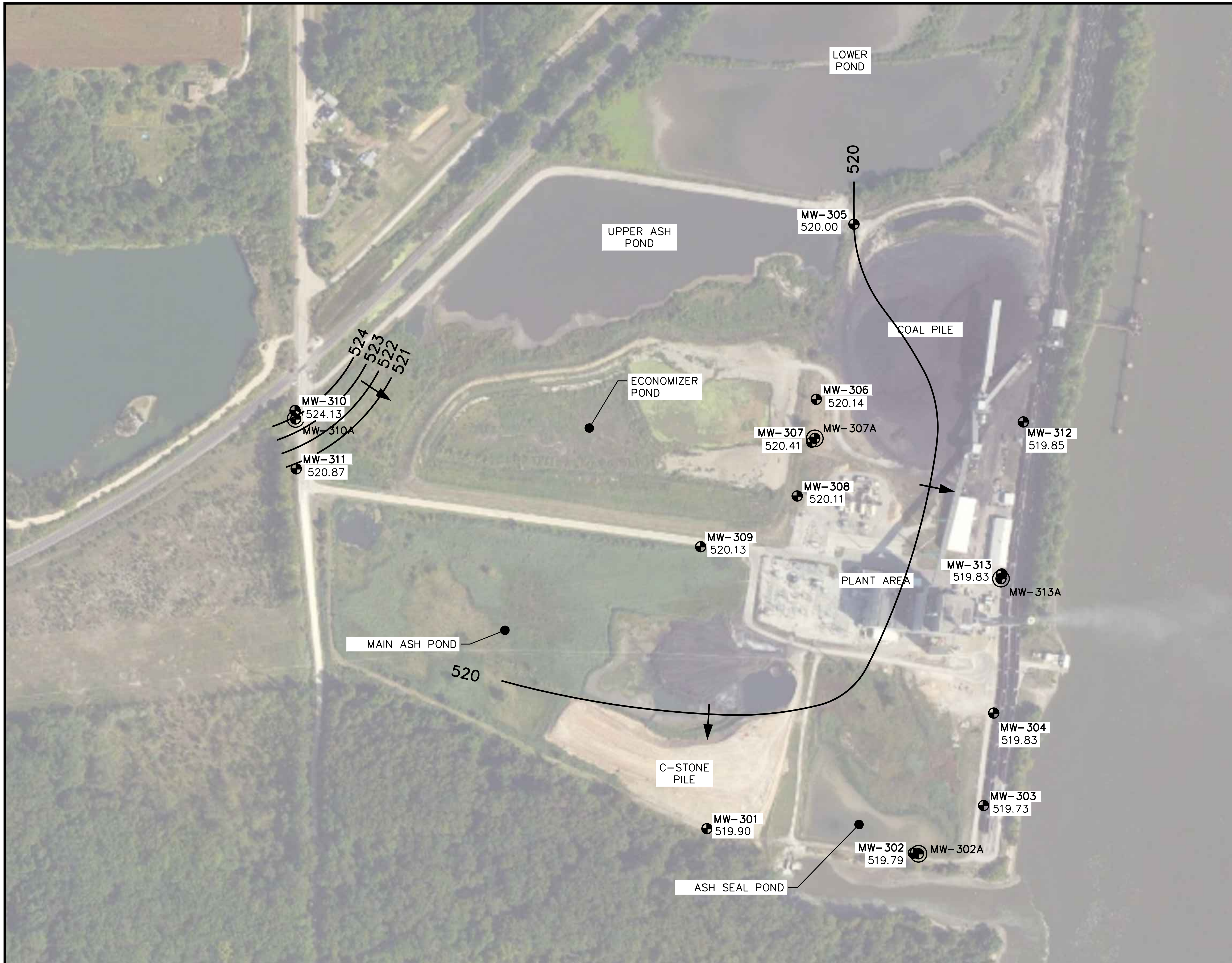

LEGEND

- MONITORING WELL
- DEEP PIEZOMETER
- ELEVATION CONTOUR
- APPROXIMATE FLOW DIRECTION

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW301, MW302, AND MW309-MW311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-301 THROUGH MW-311 WERE SURVEYED BY FRENCH-RENEKER ASSOCIATES OF FRANKLIN, IA ON MARCH 16, 2016.
4. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
5. DEEP PIEZOMETERS MW-302A, MW-307A, MW-310A, AND MW-313A WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN JUNE-JULY 2020.
6. GROUNDWATER ELEVATION ESTIMATED BASED ON MONITORING WELLS SCREENED BELOW THE POTENTIOMETRIC SURFACE IN THE SAND UNIT.

N

300 0 300

SCALE: 1" = 300'

PROJECT NO.	252191680	DRAWN BY:	BSS/KP
DRAWN:	09/18/2020	CHECKED BY:	MDB
REVISED:	09/24/2020	APPROVED BY:	TK 10/21/20

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY
4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

LOW POTENTIOMETRIC SURFACE MAP
SEPTEMBER 9, 2020

FIGURE 5

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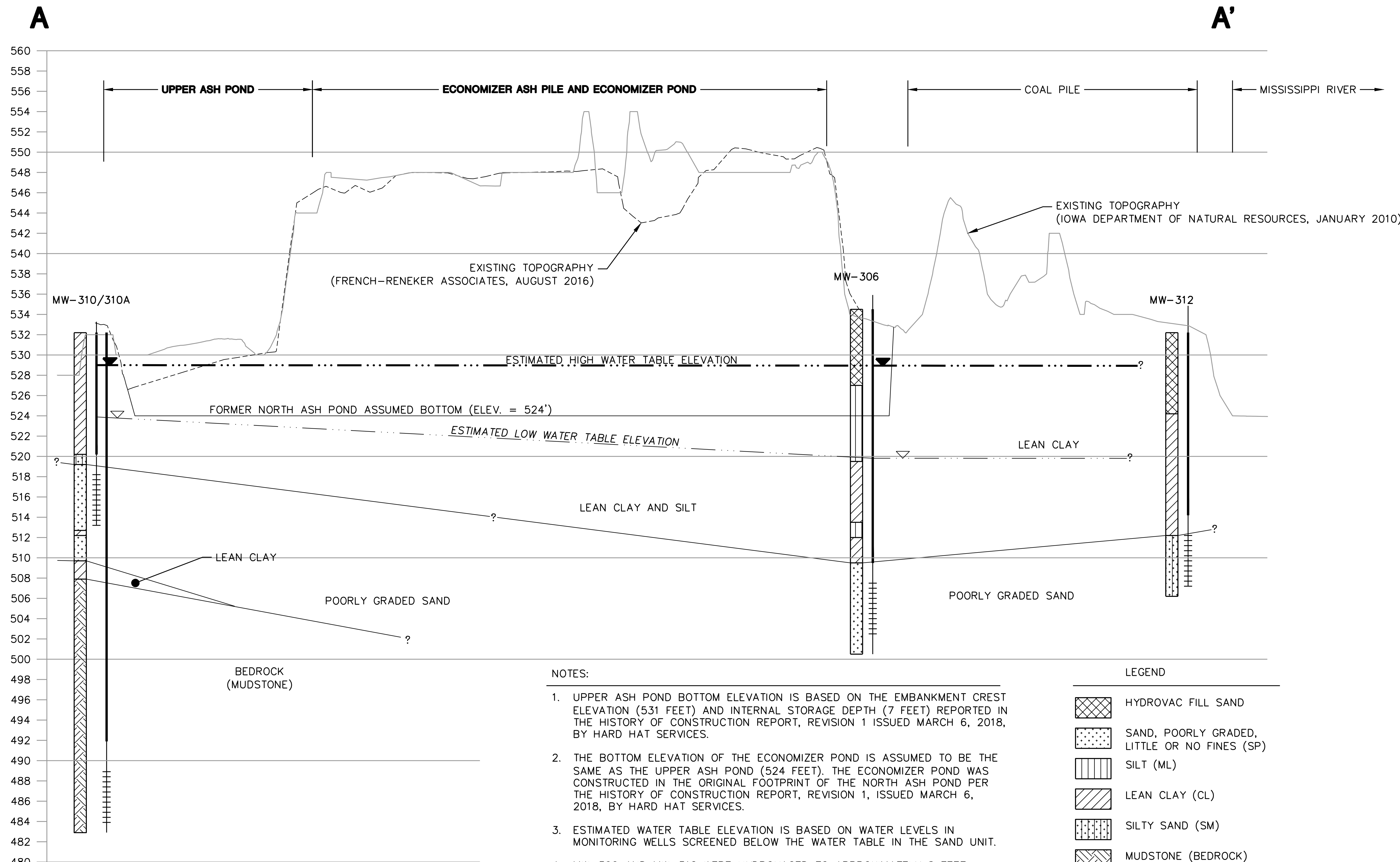
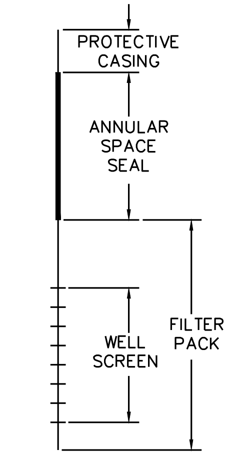


NOTES:

1. UPPER ASH POND BOTTOM ELEVATION IS BASED ON THE EMBANKMENT CREST ELEVATION (531 FEET) AND INTERNAL STORAGE DEPTH (7 FEET) REPORTED IN THE HISTORY OF CONSTRUCTION REPORT, REVISION 1 ISSUED MARCH 6, 2018, BY HARD HAT SERVICES.
2. THE BOTTOM ELEVATION OF THE ECONOMIZER POND IS ASSUMED TO BE THE SAME AS THE UPPER ASH POND (524 FEET). THE ECONOMIZER POND WAS CONSTRUCTED IN THE ORIGINAL FOOTPRINT OF THE NORTH ASH POND PER THE HISTORY OF CONSTRUCTION REPORT, REVISION 1, ISSUED MARCH 6, 2018, BY HARD HAT SERVICES.
3. ESTIMATED WATER TABLE ELEVATION IS BASED ON WATER LEVELS IN MONITORING WELLS SCREENED BELOW THE WATER TABLE IN THE SAND UNIT.
4. MW-306 AND MW-312 WERE HYDROVACED TO APPROXIMATELY 8 FEET. HYDROVACING IS PERFORMED TO DETERMINE IF UNDERGROUND UTILITIES ARE PRESENT. HIGH PRESSURE WATER AND A VACUUM ARE USED TO CLEAR THE BOREHOLE. AFTER HYDROVACING WAS COMPLETE THE BOREHOLE WAS FILLED WITH SAND TO COMPLETE THE BOREHOLE DRILLING PROCESS.

LEGEND

- HYDROVAC FILL SAND
- SAND, POORLY GRADED, LITTLE OR NO FINES (SP)
- SILT (ML)
- LEAN CLAY (CL)
- SILTY SAND (SM)
- MUDSTONE (BEDROCK)
- WATER LEVEL AT MONITORING WELL, APRIL 2019
- WATER LEVEL AT MONITORING WELL, AUGUST 2017



WELL DETAIL

0 200

HORIZONTAL SCALE: 1" = 200'
VERTICAL SCALE: 1" = 10'
VERTICAL EXAGGERATION = 20X

PROJECT NO.	25219168.00	DRAWN BY:	KP
DRAWN:	06/12/2019	CHECKED BY:	MDB
REVISED:	09/24/2020	APPROVED BY:	TK

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY
4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

GEOLOGIC CROSS SECTION

FIGURE 6

I:\2521916□.00\Drawings\□□A□os□re\□ross Section.dwg, 9/2□/2020 9:□9:□2 AM

11/25/2020 - Classification: Internal - ECRM7803923

Appendix A

Regional Geologic and Hydrogeologic Information

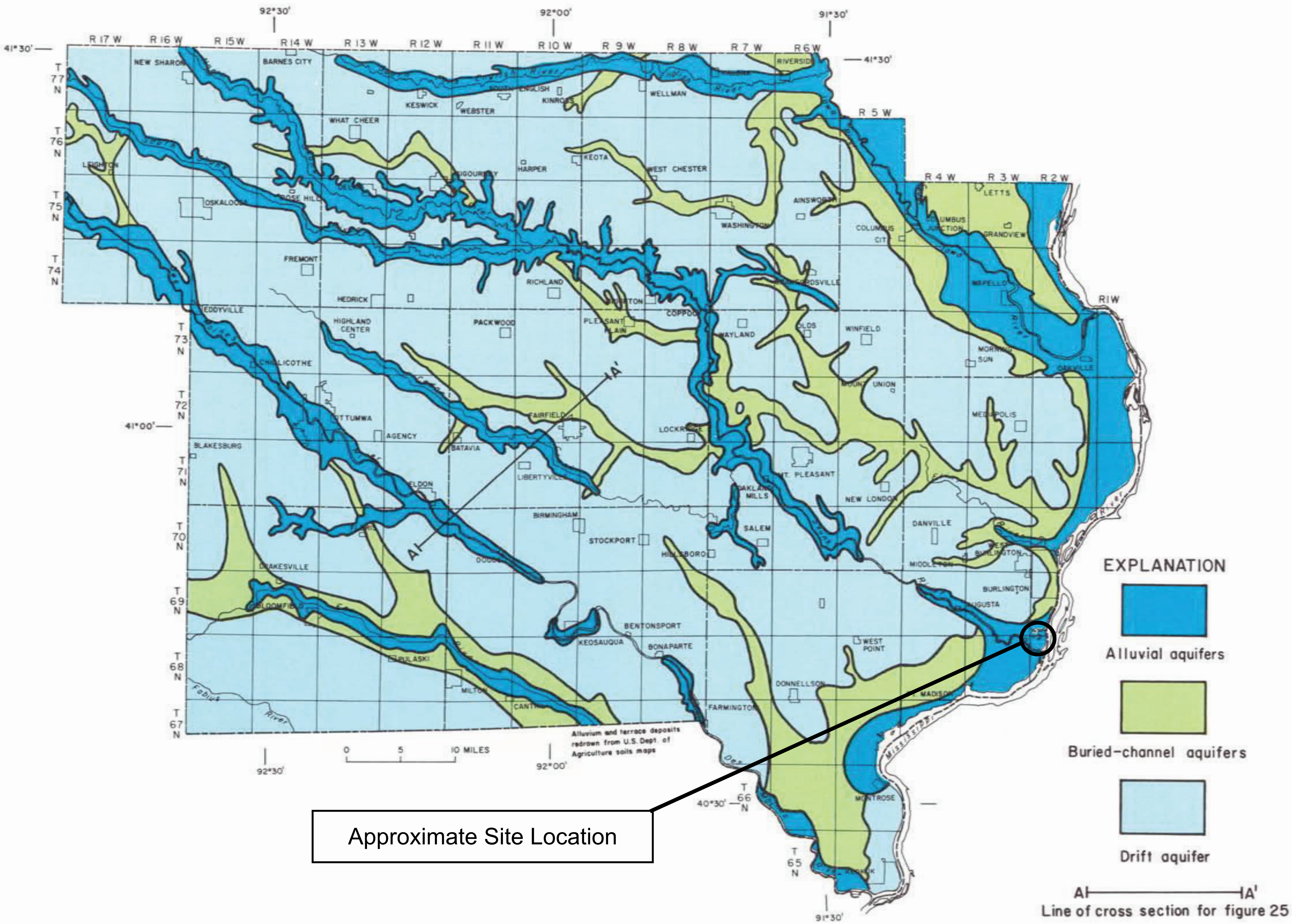


Figure 24.—Areal distribution of surficial aquifers

Source: Coble, R.W., The Water Resources of Southeast Iowa, Iowa Geological Survey Water Atlas Number 4, 1971.

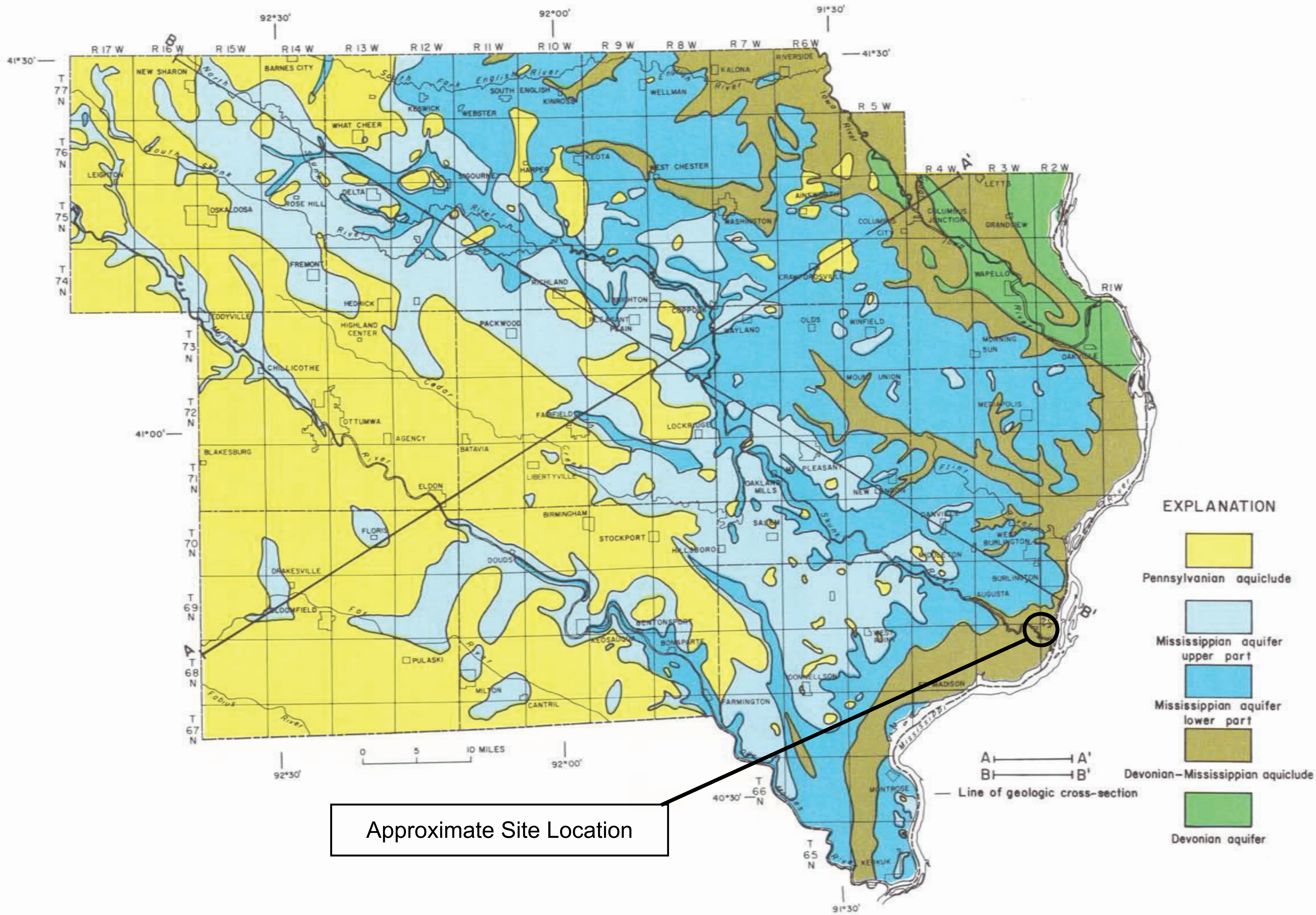


Figure 27.—Bedrock hydrogeologic map

Source: Coble, R.W., The Water Resources of Southeast Iowa, Iowa Geological Survey Water Atlas Number 4, 1971.

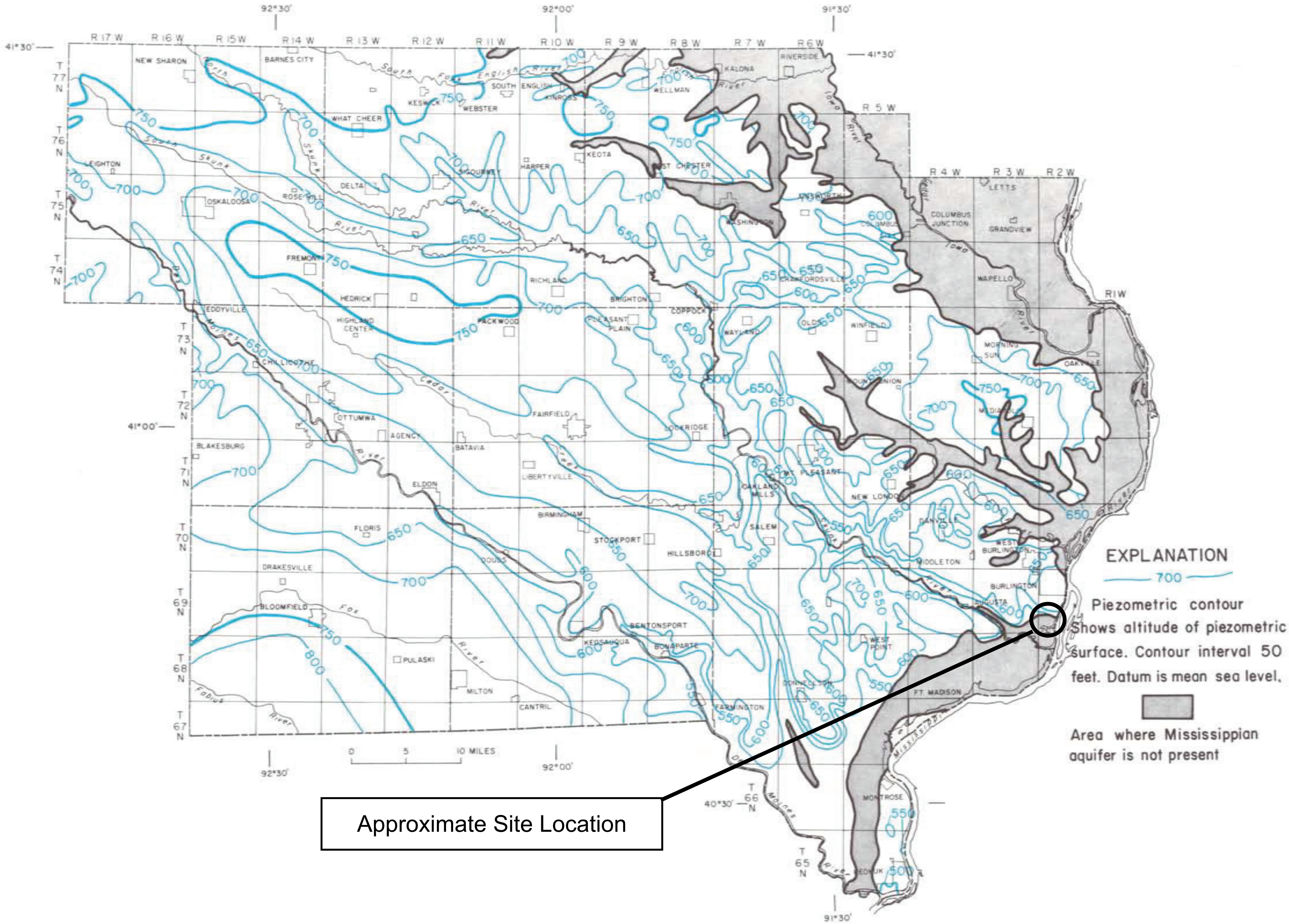


Figure 41.—Altitude of the water levels in wells tapping the Mississippian aquifer

Source: Coble, R.W., The Water Resources of Southeast Iowa, Iowa Geological Survey Water Atlas Number 4, 1971.

Appendix B

Boring Logs

SCS ENGINEERS — **SOIL BORING LOG INFORMATION**

Environmental Consultants and Contractors

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-301

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	2/29/2016	2/29/2016	Direct Push 4-1/2/HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-301	Feet	536.0 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,382 N, 2,300,041 E S/C/N
SW 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W

Lat ___° ___' ___"
Long ___° ___' ___"

Local Grid Location: ☐ N ☐ E; Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
			10–15	LEAN CLAY WITH SAND, very dark gray (10YR 3/1).	CL									
S1	16		11							W				
S2	45		14							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718 Tel: 608-224-2830 Fax:

Boring Number MW-301

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			16, 17	LEAN CLAY WITH SAND, very dark gray (10YR 3/1). *(continued)*	CL									
S3	37		18, 19	POORLY GRADED SAND, very dark gray (10YR 3/1).	SP					W				
			20	SILT WITH SAND, very dark gray (10YR 3/1).	ML									
			21	POORLY GRADED SAND, very dark gray (10YR 3/1).	SP									
S4	24		22, 23	SANDY SILT, very dark gray (10YR 3/1).	MLS					W				
S5	NA		24, 25, 26, 27, 28, 29	POORLY GRADED SAND, very dark gray (10YR 3/1).	SP					W				Recovery NA sleeve stuck in discrete sampler.
				End of Boring at 29.50 feet bgs.										

SCS ENGINEERS | **SOIL BORING LOG INFORMATION**

Environmental Consultants and Contractors

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-302

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	2/29/2016	2/29/2016	Direct Push 4-1/2/HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-302	Feet	533.2 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,310 N, 2,300,647 E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W

Lat ___° ___' ___" Long ___° ___' ___"

Local Grid Location: Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
S1	15		10–12	POORLY GRADED SAND WITH SILT, medium grained, very dark gray (10YR 3/1).	SP-SM					W				
S2	15		12–15	POORLY GRADED SAND, medium grained, very dark gray (10YR 3/1).	SP					W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm: SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-302

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			16	POORLY GRADED SAND, medium grained, very dark gray (10YR 3/1). *(continued)*	SP									
S3	17		17–20	LEAN CLAY, very dark gray (10YR 3/1).	CL					W				
S4	15		20–28	POORLY GRADED SAND, coarse grained, very dark gray (10YR 3/1).	SP					W				
S5	16									W				
			28	End of Boring at 28 feet bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-303

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/15/2015	12/15/2015	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-303	Feet	531.0 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,450 N, 2,300,854 E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' "
Long ° ' "
Local Grid Location ☐ N ☐ E
Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
			10–15	LEAN CLAY, dark gray (10YR 3/1).	CL									
S1	0	4 6 8 8	10–12											Rock in the end of shoe.
S2	14	2 4 4 5	12.5–14.5							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]
Firm: SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-303

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
				LEAN CLAY, dark gray (10YR 3/1). *(continued)*	CL									
S3	15	2 2 4 6	16							W				
			17											
			18											
S4	3	1 2 3 8	19							W				Rock in the end of shoe.
			20	POORLY GRADED SAND, coarse grained, very dark gray (2.5Y 3/1), some gravel.	SP									
S5	10	4 8 9 9	21							W				
			22											
			23	POORLY GRADED SAND, very dark gray (2.5Y 3/1), medium grained.	SP									
S6	14	1 2 8 9	24							W				
			25											
S7	8	4 6 8 10	26	same as above except, coarse grained.						W				
			27	End of Boring at 27.50 ft bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Remediation/Redevelopment ☐ Waste Management ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-304

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/15/2015	12/15/2015	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-304	Feet	532.2 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,721 N, 2,300,883 E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' " Long ° ' "
Local Grid Location: Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
			10–15	FAT CLAY, dark gray (10YR 3/1).	CH									
S1	12	3 4 11 14	11							W				
S2		2 3 5 5	13.5							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]

Firm: SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-304

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
				SANDY SILT, very dark gray (2.5Y 3/1), fine grained.										
S3	14	1 1 2 4	16		ML					W				
			17											
			18	POORLY GRADED SAND, very dark gray (2.5Y 3/1), medium grained.										
S4	14	1 2 3	19							W				
			20											
S5	24	2 3 5 8	21							W				
			22		SP									
			23	Same as above except, coarse grained.										
S6	12	3 5 6 7	24							W				
			25											
S7	12	3 6 11 16	26							W				
			27	End of boring at 27 feet bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name		License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station	SCS#: 25215135.80		MW-305

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/17/2015	12/17/2015	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-305	Feet	530.9 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 280,157 N, 2,300,473 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W

Lat ___° ___' ___"
Long ___° ___' ___"

Local Grid Location
☐ N ☐ E
Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–5	FILL, boring location was cleared to 5' bgs by hydrovac, then back filled.	FILL									
			5	SILT, ash, black (2.5Y 2.5/1), (fill).	ML									
S1	14	13 30 20 12	6							M				
S2	6	3 4 2 1	8.5							M				
			10	LEAN CLAY, olive (5Y 4/4).	CL									
S3	5	4 4 6 7	11							M				
S4	10	2 4 6 8	13.5	same as above except, black (2.5Y 2.5/1).						M				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

Firm SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-305

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
				LEAN CLAY, olive (5Y 4/4). *(continued)*										
S5	14	1 1 2 3	16											
			17		CL									
			18	same as above except, very dark gray (10YR 3/1).										
S6	16	1 1 2 2	19											
			20	POORLY GRADED SAND, very dark gray (10YR 3/1), coarse grained.										
S7	12	1 2 4 5	21							W				
			22											
			23											
S8	12	1 1 2 3	24		SP					W				
			25											
S9	8		26							W				
			27											
				End of Boring at 27.50 ft bgs.										

SCS ENGINEERS | **SOIL BORING LOG INFORMATION**

Environmental Consultants and Contractors

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-306

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/16/2015	12/17/2015	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-306	Feet	534.5 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,643 N, 2,300,362 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location ☐ N ☐ E; Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–7.5	FILL, boring location was cleared to 7.5' bgs by hydrovac, then back filled.	FILL									
			7.5–15	SANDY SILT, very dark gray (2.5Y 3/1), fine grained sand.	ML									
S1	22	6 8 12 12	8–10											
S2	22	7 2 2 2	10.5–12.5							W				
S3	12	4 9 19 21	13–15							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

Firm SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-306

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
				LEAN CLAY, black (2.5Y 2.5/1).	CL									
S4	10	2 2 2 2	16							W				
			17											
			18											
S5	10	1 1 1 2	19							W				
			20											
S6	22	3 4 5	21	SANDY SILT, very dark gray (2.5 3/1), fined grained sand.	ML					W				
			22											
			23	LEAN CLAY, black (2.5Y 2.5/1).	CL									
S7	10	1 1 1 2	24							W				
			25	POORLY GRADED SAND, very dark gray (2.5Y 3/1), coarse grained.	SP									
S8	20	2 3 6 10	26							W				
			27											
			28											
S9	10	1 3 3 5	29							W				
			30											
S10	10	2 2 3 8	31							W				
			32											
			33											
			34	End of boring at 34 ft bgs.										

SCS ENGINEERS — **SOIL BORING LOG INFORMATION**

Environmental Consultants and Contractors

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-307

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/16/2015	12/16/2015	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-307	Feet	534.3 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,517 N, 2,300,349 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' " Long ° ' "
Local Grid Location ☐ N ☐ E Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–7.5	FILL, boring location was cleared to 7.5' bgs by hydrovac, then back filled.	FILL									
S1	0		7.5–10	SILT, ash, (fill).	ML									
S2	16	13 8 6 11	10–	SANDY SILT, very dark gray (2.5Y 3/1), sand is fine grained.	ML					W				
S3	15	4 9 6 3	–15							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: 608-224-2830 Fax:

Boring Number MW-307

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
S4	18	1 3 5 5	16, 17	SANDY SILT, very dark gray (2.5Y 3/1), sand is fine grained. *(continued)*	ML					W				
S5	20	1 2 2 2	18, 19	LEAN CLAY, black (10YR 2/1).	CL					W				
S6	16	1 2 4 6	20, 21, 22	POORLY GRADED SAND, very dark gray (2.5Y 3/1), coarse grained.	SP					W				
S7	10	1 2 4 4	23, 24, 25							W				
S8	12	2 2 3 4	26, 27							W				
				End of boring at 27 ft bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-308

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Mike Mueller Cascade Drilling	12/15/2015	12/16/2015	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-308	Feet	534.9 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,359 N, 2,300,306 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ° ' " Long ° ' "
Local Grid Location ☐ N ☐ E Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	FILL, boring location was cleared to 5' bgs by hydrovac, then back filled.	FILL									
			5	SANDY SILT, olive brown (2.5Y 4/3).										
S1	14	22 12 13 15	6							W				
S2	18	2 2 4 8	8.5							W				
			10		MLS									
S3	18	1 2 2 50	11							W				
S4	14	3 15 50	13.5							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature]
Firm: SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-308

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
				LEAN CLAY, black (2.5Y 2.5/1).	CL									
S5	12	6 4 2 4	16							W				
			17											
			18											
S6	12	5 6 5 10	19							W				
			20	SILT, very dark gray (7.5YR 3/1), trace sand.	ML									
S7	18	1 1 1 2	21							W				
			22											
			23	POORLY GRADED SAND, very dark gray (2.5Y 3/1), coarse grained.	SP									
S8	10	1 12 13 18	24							W				
			25											
S9	12	2 6 8 10	26							W				
			27											
			28											
S10		2 2 6 8	29							W				
				End of Boring at 29.5 ft bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-309

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	3/1/2016	3/1/2016	4-1/2 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-309	Feet	534.1 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,210 N, 2,300,022 E S/C/N
SW 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W

Lat ___ ° ___ ' ___ "
Long ___ ° ___ ' ___ "

Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–10	FILL, boring location was cleared to 10' bgs by hydrovac, then back filled.	FILL									
			10	LEAN CLAY, olive brown (2.5Y 4/3).	CL									
S1	14		11							W				
			12	Same as above except, gray (2.5Y 6/1).										
S2	34		14							W				
			15											

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: 608-224-2830 Fax:

Boring Number MW-309

Sample									Soil Properties					
Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
				LEAN CLAY, olive brown (2.5Y 4/3). *(continued)*										
			16	Same as above except, very dark gray (2.5Y 3/1).										
			17		CL									
S3	34		18							W				
			19	POORLY GRADED SAND, coarse grained, very dark gray (10YR 3/1).										
			20											
			21											
S4	31		22		SP					W				
			23											
			24											
			25	End of Boring at 25 feet bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-310

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	3/1/2016	3/1/2016	Direct Push 4-1/2/HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-310	Feet	532.2 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,610 N, 2,298,832 E S/C/N
NE 1/4 of SE 1/4 of Section 30, T 69 N, R 2 W
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location ☐ N ☐ E
Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	LEAN CLAY WITH SAND, dark olive brown (2.5Y 3/3).										
S1	13		2							M				
S2	33		6		CL					M				
			7	Same as above except, very dark gray (2.5Y 3/1).										
S3	22		10	Trace organics.						M				
			12	SILTY SAND, very dark grayish brown (2.5Y 3/2).	SM									
			13	POORLY GRADED SAND, coarse grained, very dark grayish brown (2.5Y 3/2).	SP									
S4	31		14							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature] Firm SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-310

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
S5	35		16–19	POORLY GRADED SAND, coarse grained, very dark grayish brown (2.5Y 3/2). *(continued)*	SP					W				
			20	LEAN CLAY, dark gray (2.5Y 4/1).	CL									
S6	NA		20–22	POORLY GRADED SAND, very dark grayish brown (2.5Y 3/2).	SP					W				Sample stuck in discrete sampler. Refusal @24'.
			23–24	LEAN CLAY, dark gray (2.5Y 4/1), (weathered bedrock).	CL									
			24	End of Boring at 24 feet bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Burlington Generating Station SCS#: 25215135.80		MW-311

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Collins Direct Push Analytical	3/1/2016	3/1/2016	Direct Push 4-1/2/HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-311	Feet	532.7 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,439 N, 2,298,835 E S/C/N
NE 1/4 of SE 1/4 of Section 30, T 69 N, R 2 W
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location
Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0	TOPSOIL.	TOPSOIL									
			0.5	LEAN CLAY, dark olive brown (2.5Y 3/3).	CL									
S1	14		2							M				
			4	POORLY GRADED SAND, yellowish brown (10YR 5/8), coarse grained.	SP									
S2	8		6							M				
			8	LEAN CLAY, very dark gray (2.5Y 3/1).	CL									
S3	6		10							M				Rock in shoe.
S4	25		14							M				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature]

Firm SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: 608-224-2830
Fax:

Boring Number MW-311

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
				LEAN CLAY, very dark gray (2.5Y 3/1). *(continued)*	CL									
S5	34		16 – 19	SILTY SAND, black (2.5Y 2.5/1).	SM					W				
			19 – 20	POORLY GRADED SAND, very dark grayish brown (2.5Y 3/2).	SP									
S6	40		20 – 23	SILTY SAND, very dark grayish brown (2.5Y 3/2).	SM					W				
			23 – 24	SILT, very dark grayish brown (2.5Y 3/2).	ML									
S7	45		24 – 28	LEAN CLAY, dark gray (2.5Y 4/1), laminated, organics.	CL					W				
			28 – 29	POORLY GRADED SAND, very dark grayish brown (2.5Y 3/2).	SP									
S8			29 – 32	LEAN CLAY, dark gray (2.5Y 4/1), laminated, organics. Same as above except, dark greenish gray (5GY 4/1), shells.	CL					W				
			32	End of Boring at 32 feet bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IP&L - Burlington Generating Station SCS#: 25218220.00		MW313

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Roberts Environmental Drilling	5/21/2019	5/21/2019	4.25" HSA

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW313	Feet	Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☐
State Plane N, E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2

Lat ___ ° ___ ' ___ "
Long ___ ° ___ ' ___ "

Local Grid Location
☐ N ☐ E
Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Des Moines	Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–8	Hydrovaced to 8'.										
			8	LEAN CLAY, (GLEY1 4/10Y), trace coarse sand.	CL									
	8	3 1 4 5	9							M				
	8	1 1 3 4	11							M				
			12	Trace organic material										
	8	1 1 2 2	13							M				
			15											

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers 3900 kilroy Airport Way Long Beach, CA 90806	Tel: Fax:

Boring Number MW313

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
	12	1 1 2 2		LEAN CLAY, (GLEY1 4/10Y), trace coarse sand. *(continued)*	CL					M				
			16	Same as above but dark gray, (10YR 2/1).										
		1 1 2 2	17							M				
			18											
		1 1 2 2	19							M				
			20											
	18	1 1 3 4	21							M				
			22											
	24	3 2 3 4	23							M				
			24	Small sand lenses.										
	18	1 1 2 8	25							M				
			26	POORLY GRADED SAND, coarse.	SP									
	4		27							W				
			28											
	10	3 2 4 6	29							W				
			30											
	0	1 3 8 7	31							W				
			32	End of Boring at 32 feet.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name: IP&L - Burlington Generating Station SCS#: 25218220.00	License/Permit/Monitoring Number:	Boring Number: MW312	
Boring Drilled By: Name of crew chief (first, last) and Firm: Jeff Roberts Environmental Drilling	Date Drilling Started: 5/20/2019	Date Drilling Completed: 5/20/2019	Drilling Method: 4.25" HSA
Unique Well No.: / DNR Well ID No.: / Common Well Name: MW312	Final Static Water Level: Feet	Surface Elevation: Feet	Borehole Diameter: 8.5 in
Local Grid Origin ☐ (estimated: ☐) or Boring Location ☐ State Plane N, E S/C/N; SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2	Lat ___° ___' ___" Long ___° ___' ___"	Local Grid Location: ☐ N Feet ☐ S; ☐ E Feet ☐ W	
Facility ID: / County: Des Moines	Civil Town/City/ or Village: Burlington		

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–8	Hydrovaced to 8'.										
	4	3 3 6 7	8–10	LEAN CLAY, teal/blue, (GLEY1 5/10 GY), trace coarse sand.	CL					M				
	18	3 4 5 7	10–12	same as above but dark green, (GLEY1 3/10 GY), with gravel.	CL					M				
	10	1 2 5 8	12–14	trace organic material	CL					M				
			14–15	same as above but dark green, (10YR 2/1).	CL									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature] | Firm: SCS Engineers, 3900 kilroy Airport Way Long Beach, CA 90806 | Tel: | Fax:

Boring Number MW312

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
	24	1 4 5 6		LEAN CLAY, teal/blue, (GLEY1 5/10 GY), trace coarse sand. *(continued)*	CL					M				
			16											
			17							M				
			18											
		2 3 3 4	19							M				
			20	POORLY GRADED SAND, fine to coarse, (2.5YR 3/2).	SP									
	6	0 1 2 3	21							W				
			22											
	6	1 2 4 5	23							W				
			24											
	4		25							W				
			26	End of Boring at 26 feet.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION

Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Burlington Generating Station SCS#: 25220055.00		MW-302A

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Crank Roberts Environmental Services	6/30/2020	7/1/2020	4.25" HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			11.92 Feet	533.51 Feet MSL	8.0 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 278,310 N, 2,300,647 E S / C / N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W

Lat ____ ° ____ ' ______ "
Long ____ ° ____ ' ______ "

Local Grid Location
Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
	0		0–15	Blind drilled to 28' bgs See boring logs for MW-302 for log information from 0-25'bgs.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers	Tel: Fax:

This form is authorized by Chapters 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats. Completion of this form is mandatory. Failure to file this form may result in forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on this form is not intended to be be used for any other purpose. NOTE: See instructions for more information, including where the completed form should be sent.

SOIL BORING LOG INFORMATION SUPPLEMENT

Form 4400-122A

Boring Number MW-302A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			15–25											
S1	14	3 4 7 8	25–27	POORLY GRADED SAND, mostly fine to meium grain, trace coarse grain, gray to dark gray (5y, 4/1) , with clay lense at top of spoon. olive gray, dense.						W				
S2	3	0 2 4 5	30–32	Same, fine grain, trace coarse grain with large piece of limestone.	SP					W				Roberts began using water to keep sand from backing up into augers. Took two jar samples from 25-27' bgs.
S3	0	6 8 7 8	35–37	No returns						W				
			40											

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-302A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
S4	6	5 7 8 13	41	POORLY GRADED SAND, fine to coarse grain, with gravel, gray to dark gray (5y, 3/1), with very trace silt (same color).						W				
			42											
			43											
			44											
			45	No returns										
S5	0	4 12 16 14	46							W				Roberts changed spoon catch.
			47											
			48											
			49											
			50	POORLY GRADED SAND, fine to coarse grain, trace gravel, gray to darkish gray brown, 5y, 4/1).	SP									
S6	15	3 8 12 14	51							W				
			52											
			53											
			54											
			55	Same										
S7	14	3 6 12 18	56							W				Took two jar samples from 55-57' bgs.
			57											
			58											
			59											
			60	Same										
S8	24	6 9 13 25	61	End of Boring at 61' below ground surface. Well placed at 60' bgs.						W				Sampled to 62' bgs and augered to 61' bgs.

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SOIL BORING LOG INFORMATION
Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Burlington Generating Station SCS#: 25220055.00		MW-307A

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Crank Roberts Environmental Services	6/24/2020	7/1/2020	4.25" HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			12.09 Feet	533.94 Feet MSL	8.0 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,517 N, 2,300,349 E S/C/N
NE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location
Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
	0		0–15	Blind drilled to 20' bgs See boring logs for MW-307 for log information from 0-20'bgs.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm
	SCS Engineers Tel: Fax:

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SOIL BORING LOG INFORMATION SUPPLEMENT

Form 4400-122A

Boring Number MW-307A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
			16											
			17											
			18											
			19											
			20	SILT, dark gray (2.5y, 2.5/1), with trace sand, fine grain to cousrse.										
S1	19	3 1 0 9	21						0.75	W				Took two jar samples at 20-22' bgs.
			22											
			23		ML									
			24											
			25	Same										
				POORLY GRADED SAND, fine to medium grain, trace coarse grain, dark gray (2.5y, 2.5/1).										
S2	14	5 7 9 11	26							W				Roberts began pumping water down hole to keep sand out of augers.
			27											
			28											
			29											
			30	Same, trace silt.										
S3	8	3 6 7 7	31							W				
			32											
			33		SP									
			34											
			35	Same, fine to medium grain, grayish brown (2.5y, 3/1), trace pieces of gravel, no silt.										
S4	8	3 5 7 8	36							W				
			37											
			38											
			39											
			40											

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SOIL BORING LOG INFORMATION SUPPLEMENT

Form 4400-122A

Boring Number MW-307A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
S5	22	2 3 6 6	41	POORLY GRADED SAND, fine to medium grain, gray (2.5y, 4/1), trace gravel with 6" layer of sticks in middle of spoon.	SP					W				Large amount of sticks in center of spoon.
S6	20	4 6 11 12	46	Same, fine to coarse grain, trace gravel, gray to grayish brown (2.5y, 4/1) with trace sticks.						W				
S7	0.5	4 26 16	51	Same, no sticks.						W				Refusal last 6 inches, sand pushed up into augers and locked up spoon.
S8	20	4 9 14 19	56	Same, fine to medium grain, gray to grayish brown (2.5y, 4/1).						W				Took two jar samples from 55-57' bgs.
			60	End of boring ar 60' below ground surface. Set well from 59' bgs.										

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SOIL BORING LOG INFORMATION

Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Burlington Generating Station SCS#: 25220055.00		MW-310A

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Crank Roberts Environmental Services	6/25/2020	6/26/2020	4.25" HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			9.15 Feet	532.91 Feet MSL	8.0 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,610 N, 2,298,832 E S/C/N
NE 1/4 of SE 1/4 of Section 30, T 69 N, R 2 W

Lat ___ ° ___ ' ___ "
Long ___ ° ___ ' ___ "

Local Grid Location
Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–15	Blind drilled to 20' below ground surface. See logs for MW-310 for log information between 0-20' bgs.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm
[signature]	SCS Engineers Tel: Fax:

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SOIL BORING LOG INFORMATION SUPPLEMENT

Form 4400-122A

Boring Number MW-310A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			15–20											
S1		0 0 0 0	20–22	LEAN CLAY, gray (5Y 3/2), dense with trace sand and gravel.	CL									Took three jar samples from 20-24' bgs.
S2		4 7 11 9	22–25	POORLY GRADED SAND, fine to medium grained, grayish brown.	SP									
S3			25–30	MUDSTONE (bedrock), 0.25" size pieces and smaller of rock (silt grain size, when broken up), light gray to gray, slightly reactive with acid, with poorly graded sand (overburden), coarse grained, grayish brown.										Bedrock at 25' bgs. Switched to air rotary at 25' bgs.
S4			30–35	MUDSTONE, gray (bedrock). (Feels like clay once broken up) with much less sand.										
S5			35–40	Same, trace sand, sampled intermittently between 35-40' bgs.										

SOIL BORING LOG INFORMATION SUPPLEMENT

Form 4400-122A

Boring Number MW-310A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
	S6		41, 42, 43, 44	MUDSTONE, mostly mudstone with some poorly graded sand.										
	S7		45, 46, 47, 48, 49, 50	Same, mostly mudstone with more sand and pieces of lean clay, dark gray (most likely overburden).										
	S8			End of Boring at 50' below ground surface. Set well at 49' bgs.										Took two jar samples from 47' bgs.

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SOIL BORING LOG INFORMATION
Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

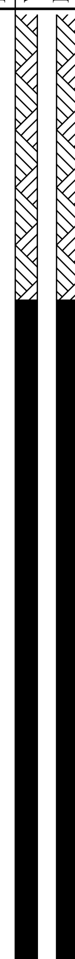
Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Burlington Generating Station SCS#: 25220055.00		MW-313A

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Jeff Crank Roberts Environmental Services	6/23/2020	6/30/2020	4.25" HSA

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			12.13 Feet	529.35 Feet MSL	8.0 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 279,130 N, 2,300,907 E S/C/N
SE 1/4 of SW 1/4 of Section 29, T 69 N, R 2 W
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location
Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Des Moines		Burlington

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–15	Blind drilled to 28' below ground surface. See logs for MW-313 for log information between 0-28' bgs.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature]	SCS Engineers	Tel: Fax:

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Boring Number MW-313A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			16											
			17											
			18											
			19											
			20											
			21											
			22											
			23											
			24											
			25											
			26											
			27											
			28	POORLY GRADED SAND, fine to medium grain, grayish brown.										
S1/S2	12	2 2 6 8	29							W				Took two jar samples from 28-30' bgs. Roberts began pumping water into augers to keep sand from backing up into augers.
			30	Same										
S3	12	5 8 11 12	31							W				
			32	Same, fine to coarse grain, grayish brown, trace gravel and clay.										
S4	14	3 4 5 5	33							W				
			34	Same	SP									
S5	5	1 3 5 6	35							W				Switched to 2' sample every five feet.
			36											
			37											
			38											
			39											
			40											

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-313A Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
S6	10	1 6 7 9	41	POORLY GRADED SAND, fine to mostly coarse grain, trace gravel, grayish brown.						W				
			42											
			43											
			44											
			45	Same, fine to medium grain, trace coarse grain.										
S7	12	3 3 8 11	46							W				
			47											
			48											
			49											
			50	Same, fine to coarse grain.										
S8	15	3 8 21 15	51		SP					W				
			52											
			53											
			54											
			55	Same, mostly fine to medium grain with trace coarse grain and gravel, grayish brown.										
S9	18	1 1 0 1	56							W				
			57											
			58											
			59											
			60	Same fine to coarse grain, grayish brown.										
S10	16	3 3 6 9	61							W				Took two jar samples from 55-57' bgs and 60-62' bgs and combined them
			62	End of boring at 62' below ground surface. Set well at 61' bgs.										

Appendix C

Hydrogeochemical Conceptual Model and Preliminary Summary of Groundwater Contaminant Attenuation

ReSolution Partners, LLC

Subject:	Hydrogeochemical conceptual model and potential remedial actions for groundwater.	
From:	Bernd W. Rehm	Date: 22 November 2020
Project:	SCS – Alliant Burlington GS CCR Evaluations	158-002c

This document provides an update of the Burlington GS site geochemistry. The hydrogeological discussion is unchanged from the September 2020 evaluation.

Hydrogeology

Beneath much of the site on the order of 25 feet of lean clay and silt overlies more than 40 feet of poorly-graded sand with occasional lenses of silt and/or clay. To the west (upgradient) edge of the site, the sand is on the order of 10 feet thick at MW-310 and missing completely at MW-11. Mudstone was encountered at a depth of about 24 feet at MW-310. Bedrock was not encountered by other borings that were on the order of 60 feet deep. The poorly-graded sands form a confined aquifer between the lean clay and the bedrock (mudstone). The Mississippi River bounds the east edge of the site. The depth of the river is unknown, but the confined aquifer is likely in contact with the river.

All the monitoring wells but MW-311 are completed as piezometers within the confined sand aquifer. There are no water table observations.

The potentiometric surface defined by the piezometers at the top of the confined aquifer varies from 531 to 524 feet near the river, to 528 to 524 at the upgradient location MW-310. The variation in elevation is probably the result of changes in Mississippi River stage, which is not known for the period of groundwater observation. During a period of low potentiometric surface (September 2020), groundwater flows from west to east under a low gradient on the order of 0.0006. Such a low gradient suggests the poorly-graded sand has a very high hydraulic conductivity. A time of high potentiometric surface suggests a high area beneath the Economizer Pond and Ash Berm and Upper Ash Ponds with radial flow to the east, south and southeast.

Four piezometers were placed at depths of about 60 feet below ground surface in June 2020. Three of the four piezometers that remained in the confined sand aquifer had vertical downward gradients of 0.002 to 0.01 in September and October 2020. The strongest downward gradient was observed at MW-207/-307A adjacent to the Economizer Pond and Ash Berm. The vertical gradients are on the order of 3 to 16 times

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greater than the horizontal gradient observed in September 2020. The fourth piezometer pair, MW-310/-310A, were completed in the confined sand aquifer and the underlying aquitard.

Groundwater Chemistry

Groundwater samples collected in 2019 and 2020 that include both field parameters and laboratory results were reviewed (Table 1). Major cation and trace element results were typically analyzed as total concentrations; the dissolved fraction plus constituents that are part of, or adsorbed to, suspended sediment and may not represent the mobile constituent concentrations. In most cases, suspended sediment loads were relatively low, ranging from 0 to 51 NTU as measured by turbidity. MW-310A was sampled with a bailer and had a turbidity of 710 NTU. These results are especially suspect. The October 2020 sampling event included analysis of dissolved lithium and molybdenum. Dissolved and total iron and manganese were also measured to evaluate the degree to which iron or manganese oxyhydroxides may be adsorbing molybdenum.

The March 2019 dissolved oxygen (DO) results for MW-301 through -308 appear to be anomalously high and were not used in the evaluation. The oxidation-reduction potential (ORP) is a key parameter controlling the fate of metals and metalloids in groundwater. The ORP was measured in most wells in June and October of 2020. However, for 13 wells the results were approximately 250 to 350 mV lower in October. Three monitoring wells sampled in September 2020 were reported with low ORPs comparable to the October results, suggesting that the low ORP values may be correct. However, most wells showed unchanged or increasing sulfate concentrations, which are not consistent with decreasing ORP values reported as low as -280 mV. It is highly unlikely that the entire aquifer would become reducing in just four months. These inconsistencies make all ORP results suspect pending future sampling and analyses.

Comparison of the total and dissolved concentrations for iron, manganese and molybdenum find the two concentrations equal, indicating that all three elements are present only in dissolved forms defined by the 0.45 µm filtration.

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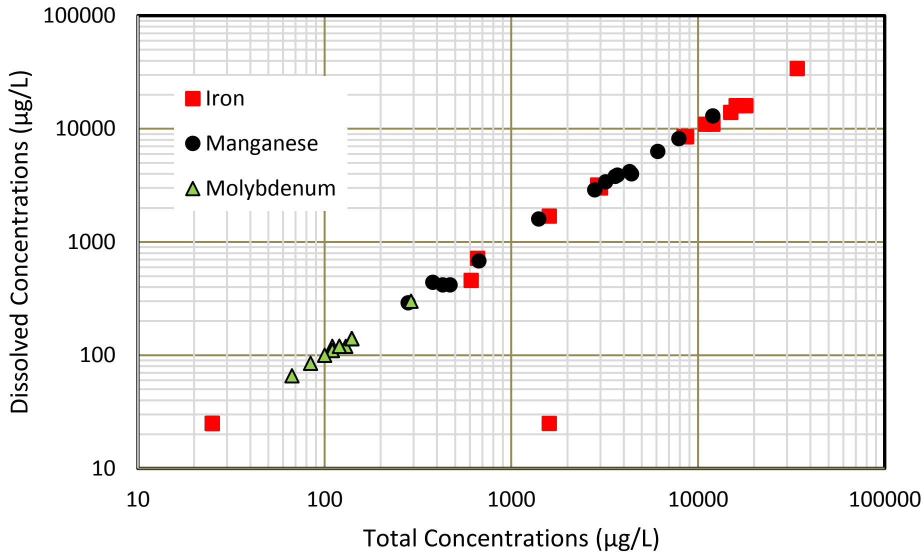
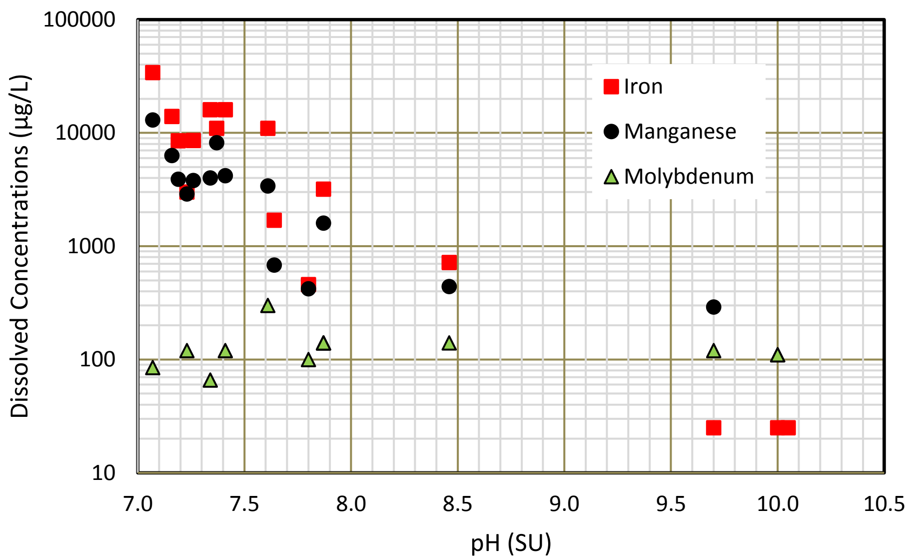


Plotting these three elements as a function of pH shows a strong negative correlation between pH and the iron and manganese concentration. This reflects the formation and precipitation of iron and manganese oxyhydroxides.



The molybdenum concentration remains constant over pH and as the oxyhydroxides form. This indicates that molybdenum is not being adsorbed by the oxyhydroxides.

Inspection of Table 1 shows that lithium, as expected, is present only in the dissolved form.

The groundwater chemistry in the confined aquifer may reflect contributions from one or more of the Upper Ash Pond, Main Ash Pond, Economizer Pond, Economizer Ash Berm

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and the Coal Pile when compared to the upgradient groundwater chemistry as described in the following paragraphs.

- Upgradient groundwater. The confined aquifer (MW-310) had a near-neutral pH (~7.5 SU) and was suboxic (DO ~0.5 mg/L). Dissolved solids as estimated by specific electrical conductance are relatively low at 900 µS/cm. Lithium and molybdenum are the most reported potential CCR constituents commonly found beneath the facility with concentrations of <2.7 and 4.9 µg/L, respectively, at the upgradient location MW-310. The most recent October 2020 results are comparable to the April 2019 and June 2020 results. The sulfate concentration is variable and averaged 47 mg/L.

  MW-310A is completed in the mudstone below the confined aquifer. MW-311 is nominally upgradient, but its completion in mudstone make its applicability for defining background chemistry for the confined sand aquifer uncertain.

- Economizer Pond and Ash Berm. For most monitoring wells at the top of the confined aquifer the pH and DO are comparable to MW-310. Wells MW-306, -307 and -308 often show pH near or greater than 10 SU. October 2020 lithium and molybdenum concentrations are comparable to earlier results and are elevated above the upgradient concentrations (typically on the order of 40 to 50 µg/L and 80 to 150 µg/L, respectively). Sulfate concentrations range from 70 to 190 mg/L.

  MW-309 is an exception with 2.4 µg/L of lithium, comparable to background. Groundwater flow at this location is not consistently from the Economizer Pond and Ash Berm. MW-313 is an exception with 205 mg/L of sulfate. The high sulfate concentrations approach that of MW-312 located downgradient of the Coal Pile.

  The deeper piezometers (MW-307A and -313A) had comparable molybdenum concentrations but lower lithium than the shallower piezometers. Sulfate at MW-313A was high at 200 mg/L, comparable to MW-313 which is downgradient of the coal pile.

- Ash Seal Pond. Shallow monitoring wells MW-302, -303 and -304 have elevated lithium (36 to 92 µg/L) and molybdenum (45 to 140 µg/L). The deeper piezometer (MW-302A) has comparable molybdenum concentrations but lower lithium than the shallower piezometers. Sulfate concentrations are the highest on the site averaging as high as 490 mg/L among the shallow wells and averaging 340 mg/L at depth.

- Upper Ash Pond. MW-305 has slightly elevated lithium concentrations and no detectable molybdenum. Sulfate was also low. The results are comparable to upgradient concentrations.

- Main Ash Pond. MW-301 is downgradient of this pond with mean concentrations of 16 µg/L lithium and 89 µg/L molybdenum. Sulfate concentrations average 250 mg/L.

- Coal Pile and Economizer Pond and Ash Berm. MW-312 has the highest molybdenum concentrations on the site (~300 µg/L), low lithium (25 µg/L) and high sulfate (220 mg/L). This may reflect molybdenum contributions from coal pile leaching.

Overall, the data suggest that lithium and molybdenum have likely been released from one of more sources to the confined sand aquifer beneath the site.

Except as noted below, the following table provides a summary of lithium and molybdenum concentrations below the BGS. Molybdenum are comparable in the shallow and deep aquifers indicating vertical downward gradients within the aquifer have carried molybdenum to depths as much as 60 feet below ground surface. The total depth of molybdenum migration is not known. Lithium concentrations decrease significantly suggesting that some form of attenuation may be present in the upper portions of the confined aquifer.

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	Shallow Piezometers		Deep Piezometers	
	Li	Mo	Li	Mo
	µg/L			
Mean	43	99	11	117
Median	48	100	11	120
Std Dev	16	28	3	5
Minimum	10	45	7	110
Maximum	92	140	13	120
Observations	37	33	6	6

The exceptions not included in the statistical summary include:

- MW-305 with low molybdenum concentrations (mean of 1.1 µg/L),
- MW-309 with low lithium concentrations (mean of 2.4 µg/L) and
- MW-312 with high molybdenum concentrations (mean of 295 µg/L).

Masses of 27 and 81 kg of lithium and molybdenum, respectively, dissolved in the groundwater beneath the BGS are estimated assuming:

- approximate plume volume of 2,240,000 m^3 assuming an area of ~159,000 m^2 and thickness of 5 to 20 m,
- total porosity of 0.3 and
- concentrations of 40 and 120 µg/L of lithium and molybdenum, respectively.

Recommendations for Additional Assessment of Site-Specific Monitored Natural Attenuation

The decrease in lithium concentration with depth suggests that natural attenuation may be sequestering lithium. To further evaluate this potential, samples of confined aquifer sand from boring depths where lithium was not detected, or was detected at low concentrations, in monitoring wells screened near those same depths, (e.g. MW-307A or -309) could be subjected to laboratory determination of lithium adsorption capacity.

Given the lack of suspended sediment and equivalence of dissolved and total trace metal concentrations, future sampling and analysis could omit collection and analysis of dissolved concentrations.

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ReSolution Partners, LLC

Future in-field analyses should pay special attention to the measurement of ORP to resolve the large differences between the June and October 2020 results.

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Table 1. Groundwater chemistry used in the evaluation of the Burlington GS.

			pH	SEC	T	DO	ORP	Turbidity	GW Eleva	Li-T	Li-D	Mo-T	Mo-D	Sulfate
			SU	µS/cm	^{o}C	mg/L	mV	NTU	Ft	µg/L		µ/L		mg/L
Upgradient	MW-310	4/4/2019	7.84	1034	10.8	1.1	---	17	528.62	<2.7	---	5.2	---	21
		6/2/2020	7.30	881	12.8	0.1	**39**	18	525.36	<2.3	---	5.8	---	100
		10/14/2020	7.34	771	16.4	0.1	**-220**	4	523.81	<2.5	---	3.6	---	19
		Mean	7.49	895	13.3	0.5	**???**	13		<2.7	---	4.9	---	47
	MW-310A	9/9/2020	7.33	1026	14.2	4.7	145	714	509.16	32	---	19	---	100
		10/16/2020	---	---	---	---	---	---	489.84	36	---	33	---	130
		Mean	7.33	1026	14.2	4.7	???	714		34	---	26	---	115
	MW-311	4/4/2019	7.64	1422	11.4	0.8	**146**	11	528.20	<2.7	---	8.5	---	230
		6/2/2020	7.10	1464	12.3	0.2	**---**	18	524.05	<2.3	---	11	---	220
		10/14/2020	7.41	1041	14.5	0.1	**-194**	2	520.59	<2.5	---	23	---	110
		Mean	7.38	1309	12.7	0.3	**???**	10		<2.7	---	14	---	187
Main Ash Pond	MW-301	3/12/2019	6.38	1055	12.6	2.6	---	17	523.38	---	---	**63**	---	---
		4/3/2019	7.53	1213	12.4	0.6	---	21	528.15	**13**	---	**77**	---	190
		10/10/2019	6.85	1063	13.9	0.2	---	13	5.26.8	**26**	---	**130**	---	390
		6/3/2020	6.99	1167	13.4	0.3	**37**	20	523.94	**16**	---	**110**	---	250
		10/16/2020	7.07	1503	13.7	0.1	**-187**	3	519.26	**10**	---	**67**	**66**	170
		Mean	6.96	1200	13.2	0.3	**???**	15		**16**	---	**89**	---	250

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			pH	SEC	T	DO	ORP	Turbidity	GW Eleva	Li-T	Li-D	Mo-T	Mo-D	Sulfate
			SU	µS/cm	^{0}C	mg/L	mV	NTU	Ft	µg/L		µg/L		mg/L
Ash Seal Pond	MW-302	3/12/2019	6.94	792	12.2	2.7	---	22	522.83	60	---	123	---	---
		4/3/2019	8.70	1164	11.4	0.6	---	19	528.21	56	---	100	---	510
		10/10/2019	7.49	1249	14.5	0.3	---	1	526.88	57	---	100	---	510
		6/3/2020	7.88	1245	12.9	0.2	37	25	523.98	55	---	140	---	490
		10/16/2020	7.87	1168	12.9	0.1	-240	0	518.94	64	64	130	120	460
		Mean	7.78	1124	12.8	0.3	???	13		58	---	119	---	493
	MW-302A	9/9/2020	7.31	1013	13.3	0.3	-142	0	519.71	11	---	120	---	340
		10/16/2020	7.26	951	13.1	0.2	-180	4	518.79	11	---	110	120	330
		Mean	7.29	982	13.2	0.2	-161	2		11	---	115	---	335
	MW-303	3/12/2019	6.46	549	13.6	2.4	---	19	522.74	52	---	---	---	---
		4/3/2019	7.79	711	12.6	0.7	---	18	528.22	52	---	110	---	120
		10/10/2019	7.13	767	14.9	0.3	---	5	526.87	46	---	76	---	84
		6/3/2020	7.12	934	14.8	0.2	58	16	523.97	48	---	66	---	100
		10/16/2020	7.19	902	13.7	0.1	-190	2	518.78	59	59	84	85	190
		Mean	7.14	773	13.9	0.3	???	12		51	---	84	---	124
	MW-304	3/12/2019	6.94	460	13.9	2.1	---	9	522.80	36	---	47	---	---
		4/3/2019	8.56	658	13.0	0.4	---	6	528.27	52	---	58	---	140
		10/10/2019	7.17	934	15.6	0.3	---	1	526.97	38	---	47	---	220
		6/3/2020	7.23	1087	14.6	0.2	52	18	524.02	47	---	45	---	250
		10/15/2020	8.46	1060	14.7	0.1	-280	0	518.69	92	93	140	140	420
		Mean	7.67	840	14.4	0.2	???	7		43	---	67	---	258
Upper Ash Pond	MW-305	4/3/2019	7.80	733	14.5	0.6	---	4	528.36	26	---	<1.1	---	10
		6/3/2020	7.12	972	15.9	0.1	40	13	524.12	28	---	<1.1	---	33
		10/15/2020	7.23	987	14.6	0.4	-175	0	519.00	34	---	1.1	---	54
		Mean	7.38	897	15.0	0.4	???	6		27	---	1.1	---	22

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			pH	SEC	T	DO	ORP	Turbidity	GW Eleva	Li-T	Li-D	Mo-T	Mo-D	Sulfate
			SU	µS/cm	⁰C	mg/L	mV	NTU	Ft	µg/L		µg/L		mg/L
Economizer Pond and Ash Berm	MW-306	3/11/2019	6.27	343	14.3	0.8	---	1	523.21	**39**	---	---	---	---
		4/3/2019	6.69	4711	13.4	0.7	---	1	528.40	**45**	---	**78**	---	110
		6/4/2020	10.48	482	14.4	0.2	**59**	16	524.45	**43**	---	**86**	---	120
		10/15/2020	10.00	454	14.1	0.1	**-237**	0	519.05	**42**	**42**	**82**	---	71
		Mean	8.36	1498	14.1	0.4	**???**	4		**42**	---	**82**	---	100
	MW-307	3/11/2019	9.71	367	14.4	1.1	---	1	523.49	**51**	---	**156**	---	---
		4/3/2019	10.39	500	13.6	0.7	---	3	528.63	**50**	---	**100**	---	120
		6/4/2020	10.03	586	14.8	0.3	**60**	14	524.62	**48**	---	**130**	---	180
		10/15/2020	10.05	565	14.0	0.1	**-270**	0	519.33	**51**	**50**	**140**	**140**	160
		Mean	10.05	505	14.2	0.4	**???**	5		**50**	---	**132**	---	153
	MW-307A	9/9/2020	7.83	585	14.4	0.2	-154	0	519.97	6.8	---	**110**	---	110
		10/14/2020	7.80	554	14.6	0.2	-190	3	519.00	8.3	---	**120**	**120**	110
		Mean	7.82	570	14.5	0.2	-172	2		**8**	---	**115**	---	110
	MW-308	3/12/2019	7.72	500	14.1	2.6	---	2	523.13	**49**	---	**135**	---	---
		4/3/2019	9.97	681	14.0	1.2	---	2	528.39	**50**	---	**110**	---	170
		10/10/2019	9.42	671	14.6	0.2	---	3	527.08	**52**	---	**120**	---	160
		6/4/2020	9.65	713	15.4	0.2	**28**	13	524.10	**48**	---	**120**	---	190
		10/14/2020	9.70	682	14.7	0.1	**-265**	0	519.02	**51**	**53**	**110**	**110**	160
		Mean	9.29	649	14.6	0.4	**???**	4		**50**	---	**119**	---	170
	MW-309	4/4/2019	7.45	997	12.6	0.5	---	20	528.40	3.3	---	**47**	---	78
		10/11/2019	---	---	---	---	---	---		<5.4	---	**90**	---	160
		6/3/2020	7.09	1086	14.8	0.2	**37**	19	524.06	2.4	---	**87**	---	180
		10/14/2020	7.61	851	14.3	0.1	**-210**	19	519.28	<2.5	---	**100**	---	160
		Mean	7.38	978	13.9	0.3	**???**	19		2.4	---	**75**	---	139

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			pH	SEC	T	DO	ORP	Turbidity	GW Eleva	Li-T	Li-D	Mo-T	Mo-D	Sulfate
			SU	µS/cm	^{0}C	mg/L	mV	NTU	Ft	µg/L		µg/L		mg/L
	MW-313	6/6/2019	6.94	1059	14.9	0.1	---	7	531.01	**43**	---	**130**	---	210
		10/10/2019	7.06	1007	16.0	0.4	---	11	526.97	**62**	---	**110**	---	210
		6/3/2020	7.03	1099	17.2	0.3	**51**	51	524.02	**52**	---	**130**	---	230
		10/15/2020	7.16	999	15.3	0.1	**-180**	14	518.70	**51**	**53**	**100**	**100**	170
		Mean	7.05	1041	15.9	0.2	**???**	21		**52**	---	**118**	---	205
	MW-313A	9/9/2020	7.60	1243	15.3	0.2	-164	0	515.36	**13**	---	**120**	---	200
		10/15/2020	7.64	1133	14.8	0.1	-190	0	518.61	**13**	---	**120**	**120**	190
		Mean	7.62	1188	15.1	0.2	-177	0		**13**	---	**120**	---	195
Coal Pile	MW-312	6/6/2019	6.99	783	14.4	0.1	---	3	531.08	**24**	---	**290**	---	220
		10/10/2019	7.19	785	15.6	8.8	---	3	526.97	**27**	---	**280**	---	230
		6/3/2020	7.13	878	14.7	0.2	**53**	21	524.05	**22**	---	**320**	---	200
		10/15/2020	7.37	854	15.1	0.1	**-200**	0	518.68	**27**	---	**290**	**300**	210
		Mean	7.17	825	15.0	0.1	**???**	7		**25**	---	**295**	---	215

March 2019 DO appear anomalous and not included in means

Measurements in bucket poured from bailer not included in evaluation.

T- Total | **12000** Concentrations exceed UPL (Background)

D- Dissolved | **130** Concentration exceeds GPS

Appendix D

Mann-Kendall Trend Test

Trend Test

Burlington Generating Station   Client: SCS Engineers   Data: BGS_Export_201121_Rev   Printed 11/21/2020, 6:00 PM

Constituent	Well	Slope	Calc.	Critical	Sig.	N	%NDs	Normality	Xform	Alpha	Method
Lithium (ug/L)	MW-301	1.496	1	13	No	6	0	n/a	n/a	0.02	NP
Lithium (ug/L)	MW-302	-3.983	-17	-17	No	7	0	n/a	n/a	0.02	NP
Lithium (ug/L)	MW-303	1.442	3	17	No	7	0	n/a	n/a	0.02	NP
Lithium (ug/L)	MW-304	-4.274	-1	-17	No	7	0	n/a	n/a	0.02	NP
Lithium (ug/L)	MW-305	-0.8548	-3	-13	No	6	0	n/a	n/a	0.02	NP
Lithium (ug/L)	MW-306	3.075	5	17	No	7	0	n/a	n/a	0.02	NP
Lithium (ug/L)	MW-307	-1.706	-2	-17	No	7	0	n/a	n/a	0.02	NP
Lithium (ug/L)	MW-308	2.663	4	17	No	7	0	n/a	n/a	0.02	NP
Lithium (ug/L)	MW-309	-0.7711	-4	-13	No	6	66.67	n/a	n/a	0.02	NP
Lithium (ug/L)	MW-310 (bg)	-1.397	-11	-13	No	6	83.33	n/a	n/a	0.02	NP
Lithium (ug/L)	MW-311 (bg)	-1.276	-11	-13	No	6	100	n/a	n/a	0.02	NP
Lithium (ug/L)	MW-312	-2.011	NaN	NaN	No	3	0	n/a	n/a	NaN	NP
Lithium (ug/L)	MW-313	9.05	NaN	NaN	No	3	0	n/a	n/a	NaN	NP
Molybdenum (ug/L)	MW-301	9.973	1	17	No	7	0	n/a	n/a	0.02	NP
Molybdenum (ug/L)	MW-302	3.46	4	17	No	7	0	n/a	n/a	0.02	NP
Molybdenum (ug/L)	MW-303	-1.639	-1	-13	No	6	0	n/a	n/a	0.02	NP
Molybdenum (ug/L)	MW-304	-30.81	-17	-17	No	7	0	n/a	n/a	0.02	NP
Molybdenum (ug/L)	MW-305	-0.2246	-10	-13	No	6	50	n/a	n/a	0.02	NP
Molybdenum (ug/L)	MW-306	0.6268	3	13	No	6	0	n/a	n/a	0.02	NP
Molybdenum (ug/L)	MW-307	-13.83	-6	-17	No	7	0	n/a	n/a	0.02	NP
Molybdenum (ug/L)	MW-308	-12.17	-11	-17	No	7	0	n/a	n/a	0.02	NP
Molybdenum (ug/L)	MW-309	21.02	9	13	No	6	0	n/a	n/a	0.02	NP
Molybdenum (ug/L)	MW-310 (bg)	1.103	11	13	No	6	0	n/a	n/a	0.02	NP
Molybdenum (ug/L)	MW-311 (bg)	-0.2897	-1	-13	No	6	0	n/a	n/a	0.02	NP
Molybdenum (ug/L)	MW-312	30.17	NaN	NaN	No	3	0	n/a	n/a	NaN	NP
Molybdenum (ug/L)	MW-313	0	NaN	NaN	No	3	0	n/a	n/a	NaN	NP

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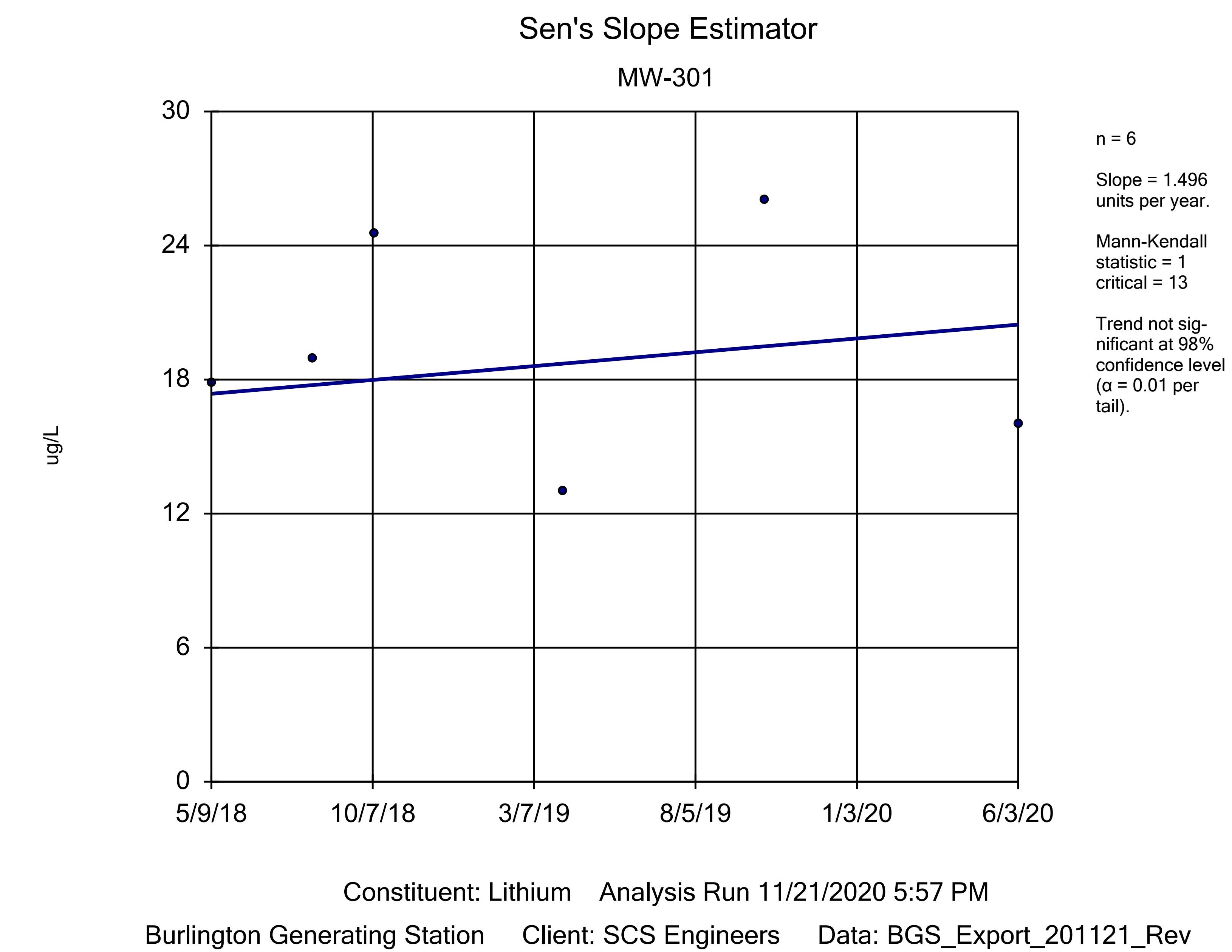
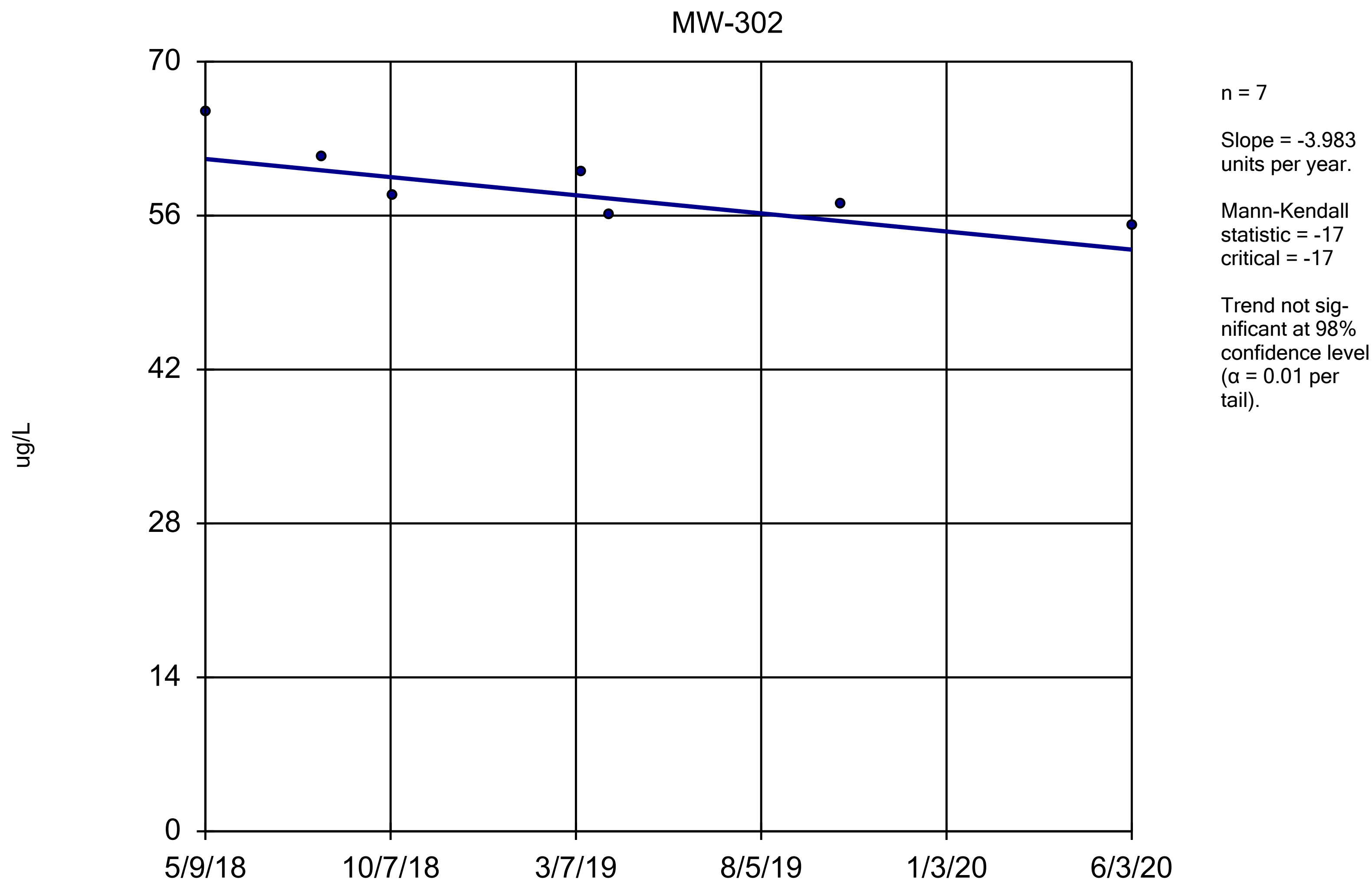


11/25/2020 - Classification: Internal - ECRM7803923

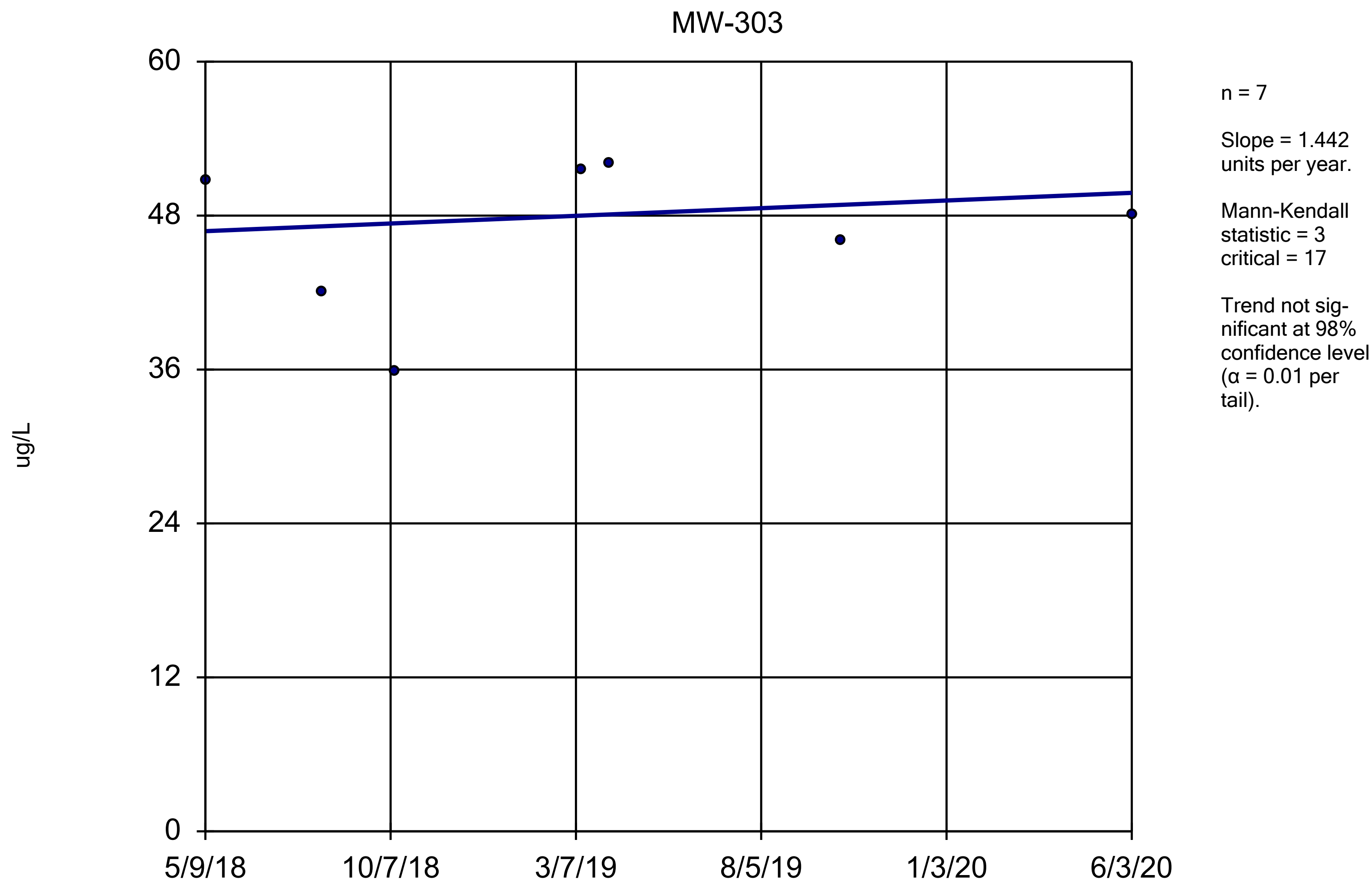
Sen's Slope Estimator



Constituent: Lithium   Analysis Run 11/21/2020 5:57 PM

Burlington Generating Station   Client: SCS Engineers   Data: BGS_Export_201121_Rev

Sen's Slope Estimator



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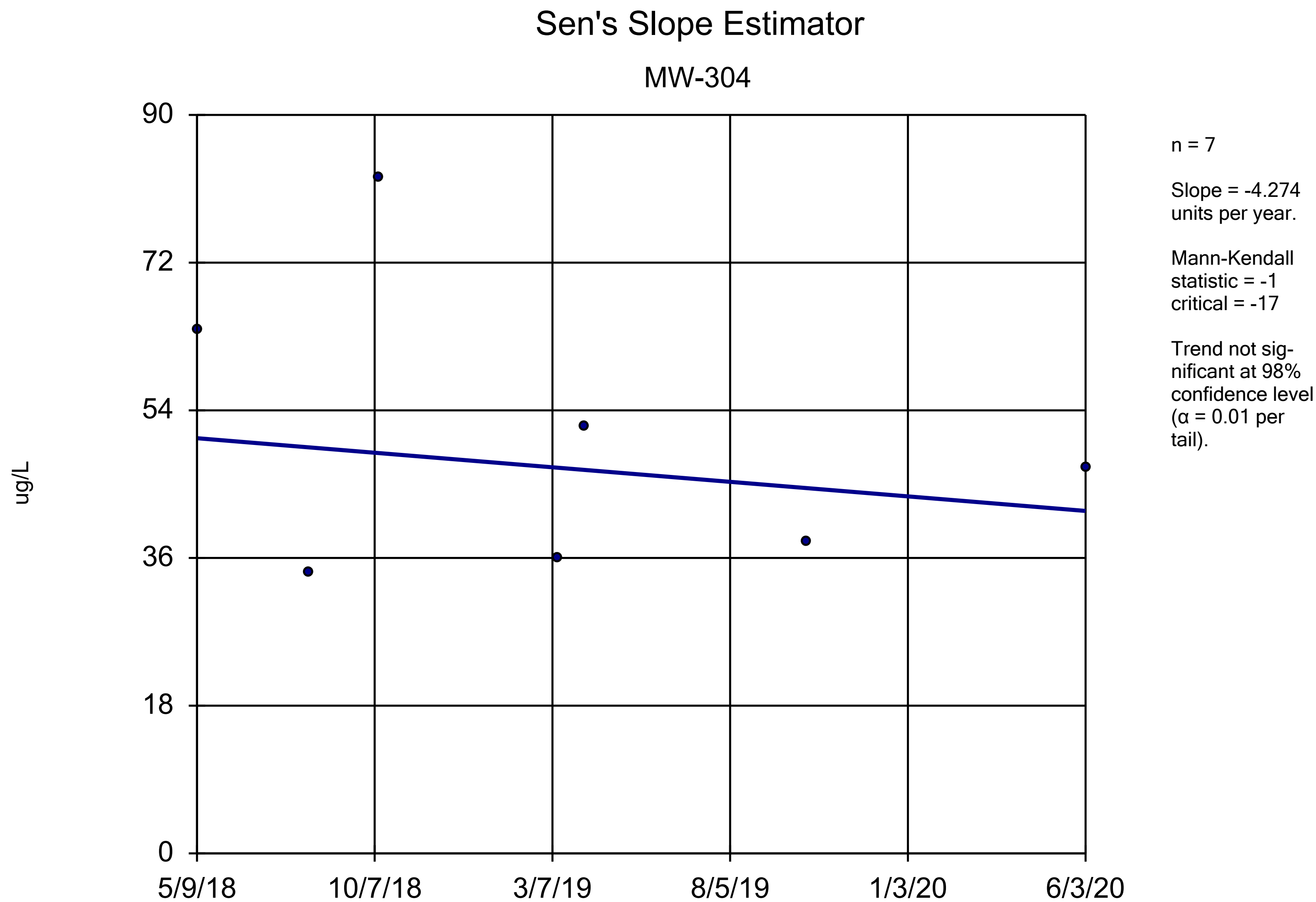

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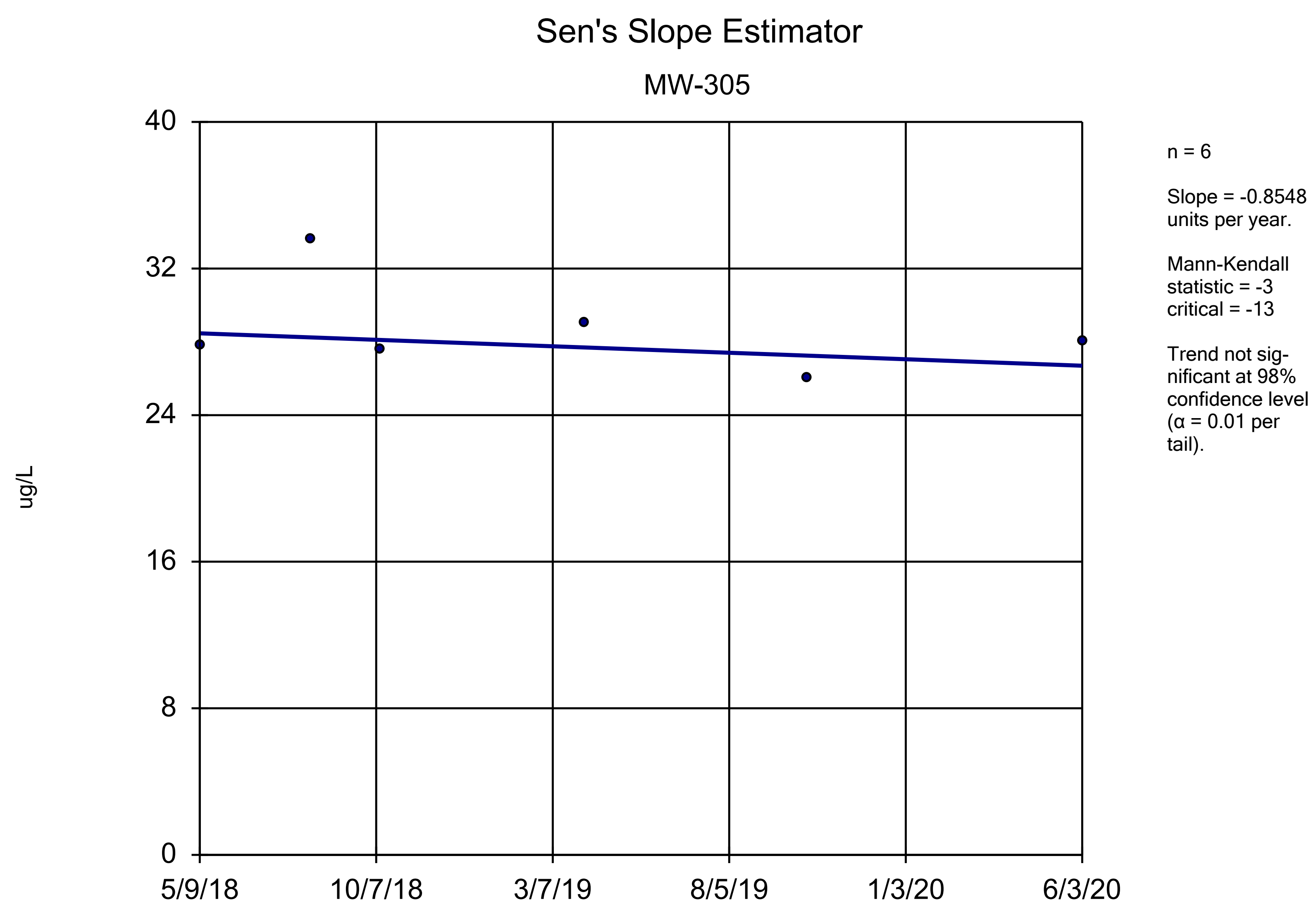
Burlington Generating Station   Client: SCS Engineers   Data: BGS_Export_201121_Rev

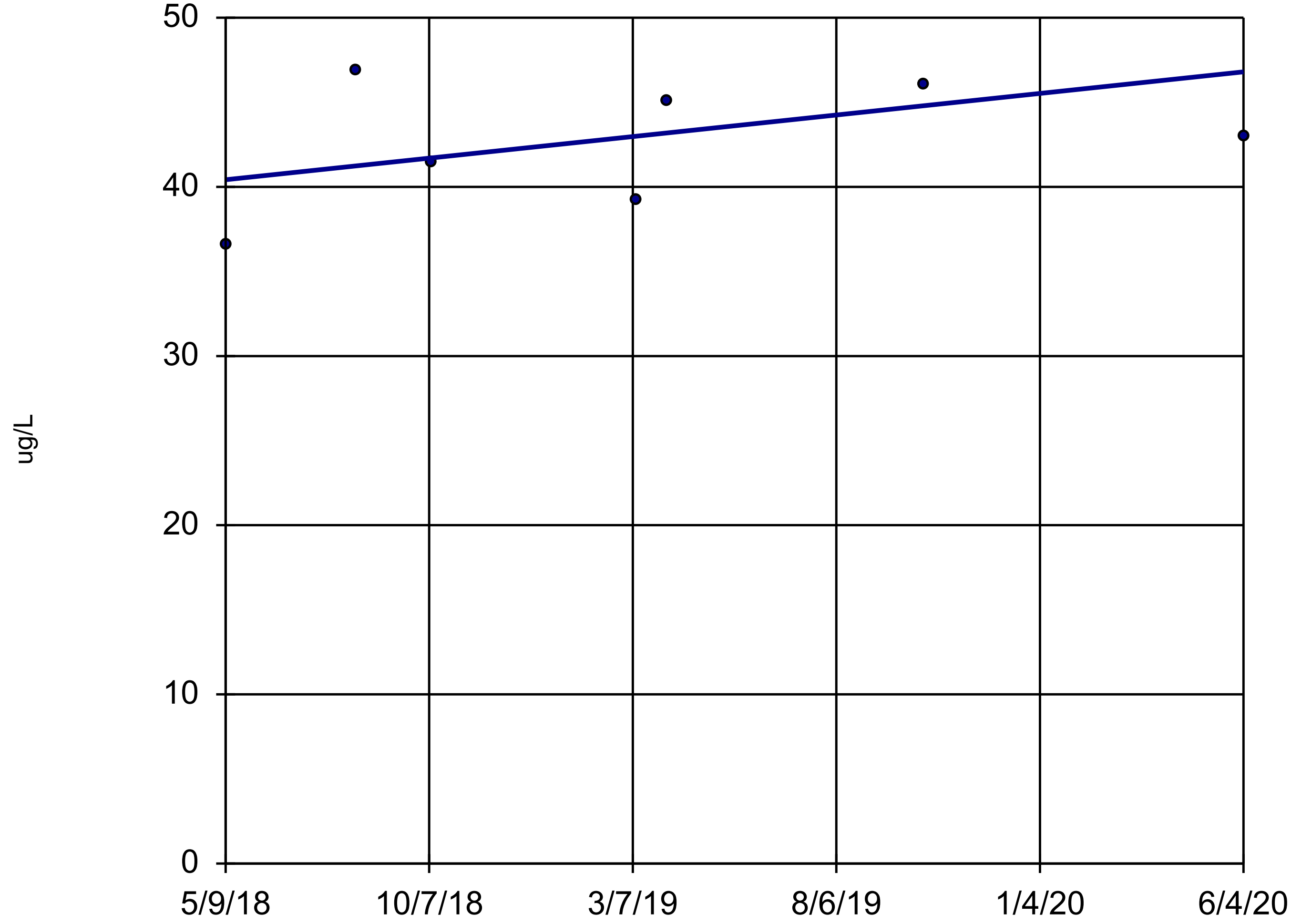


Constituent: Lithium Analysis Run 11/21/2020 5:57 PM

Burlington Generating Station Client: SCS Engineers Data: BGS_Export_201121_Rev

Sen's Slope Estimator

MW-306



n = 7

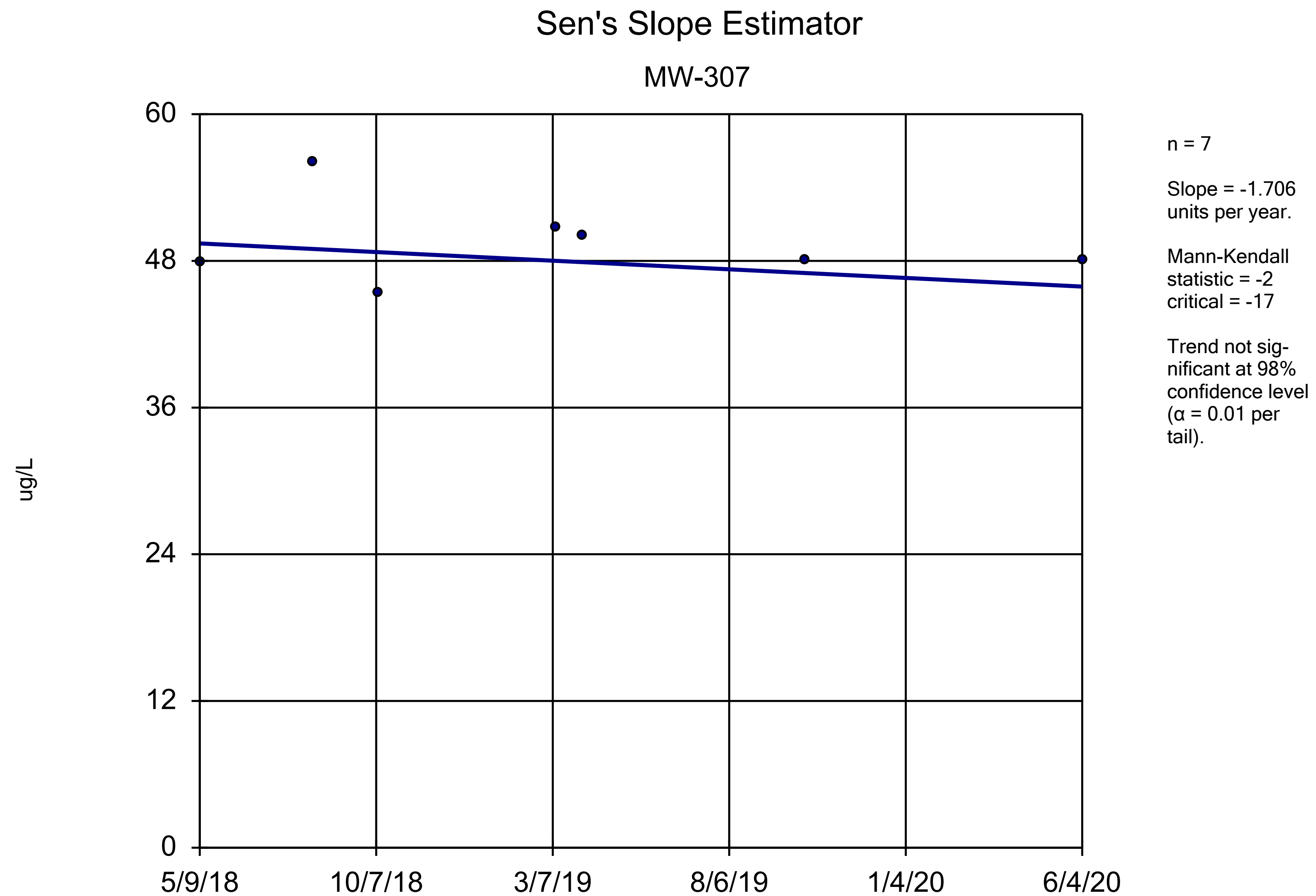
Slope = 3.075 units per year.

Mann-Kendall statistic = 5 critical = 17

Trend not significant at 98% confidence level (α = 0.01 per tail).

Constituent: Lithium   Analysis Run 11/21/2020 5:57 PM

Burlington Generating Station   Client: SCS Engineers   Data: BGS_Export_201121_Rev



Constituent: Lithium   Analysis Run 11/21/2020 5:57 PM

Burlington Generating Station   Client: SCS Engineers   Data: BGS_Export_201121_Rev

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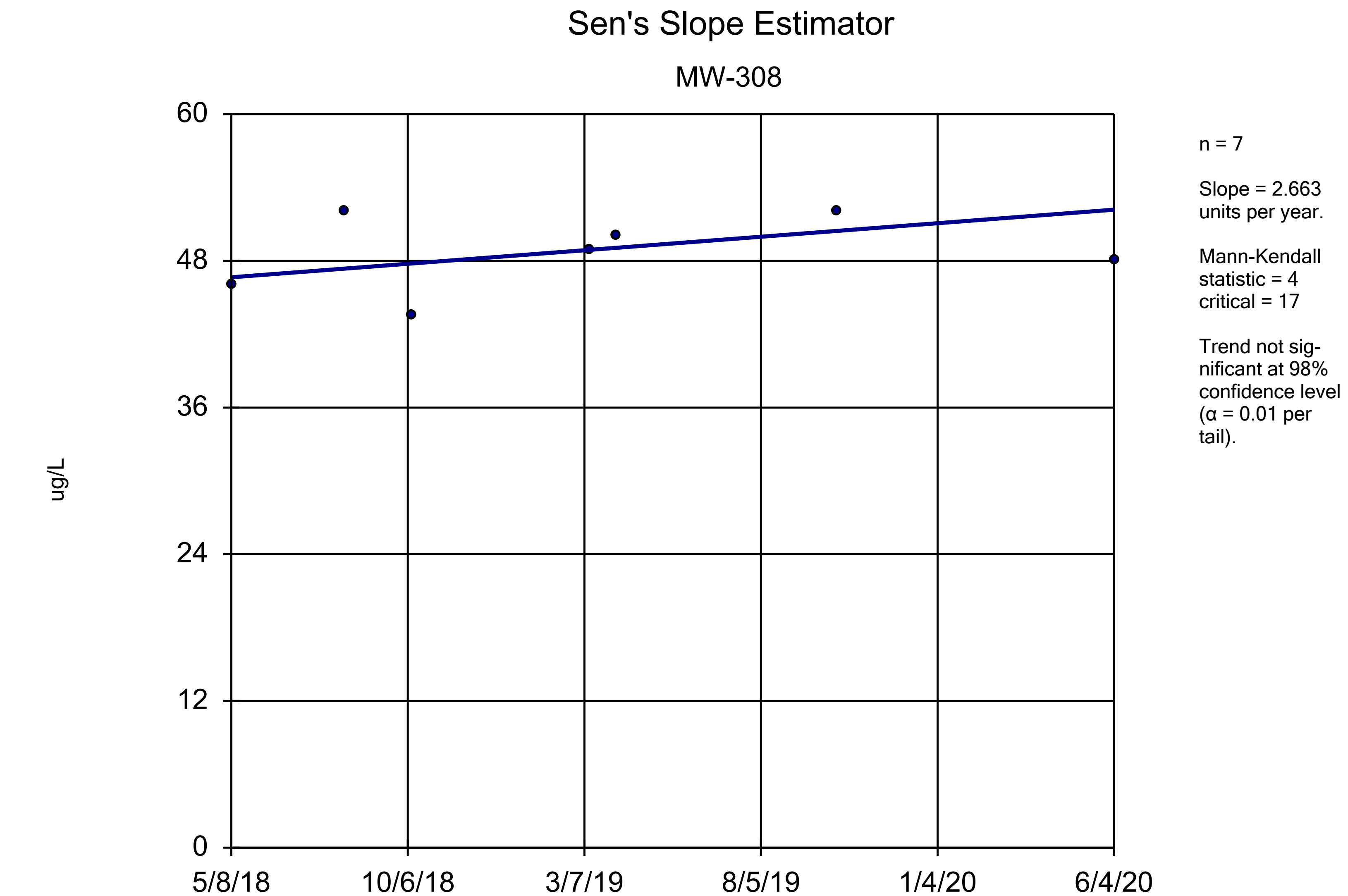

Constituent: Lithium   Analysis Run 11/21/2020 5:57 PM

Burlington Generating Station   Client: SCS Engineers   Data: BGS_Export_201121_Rev

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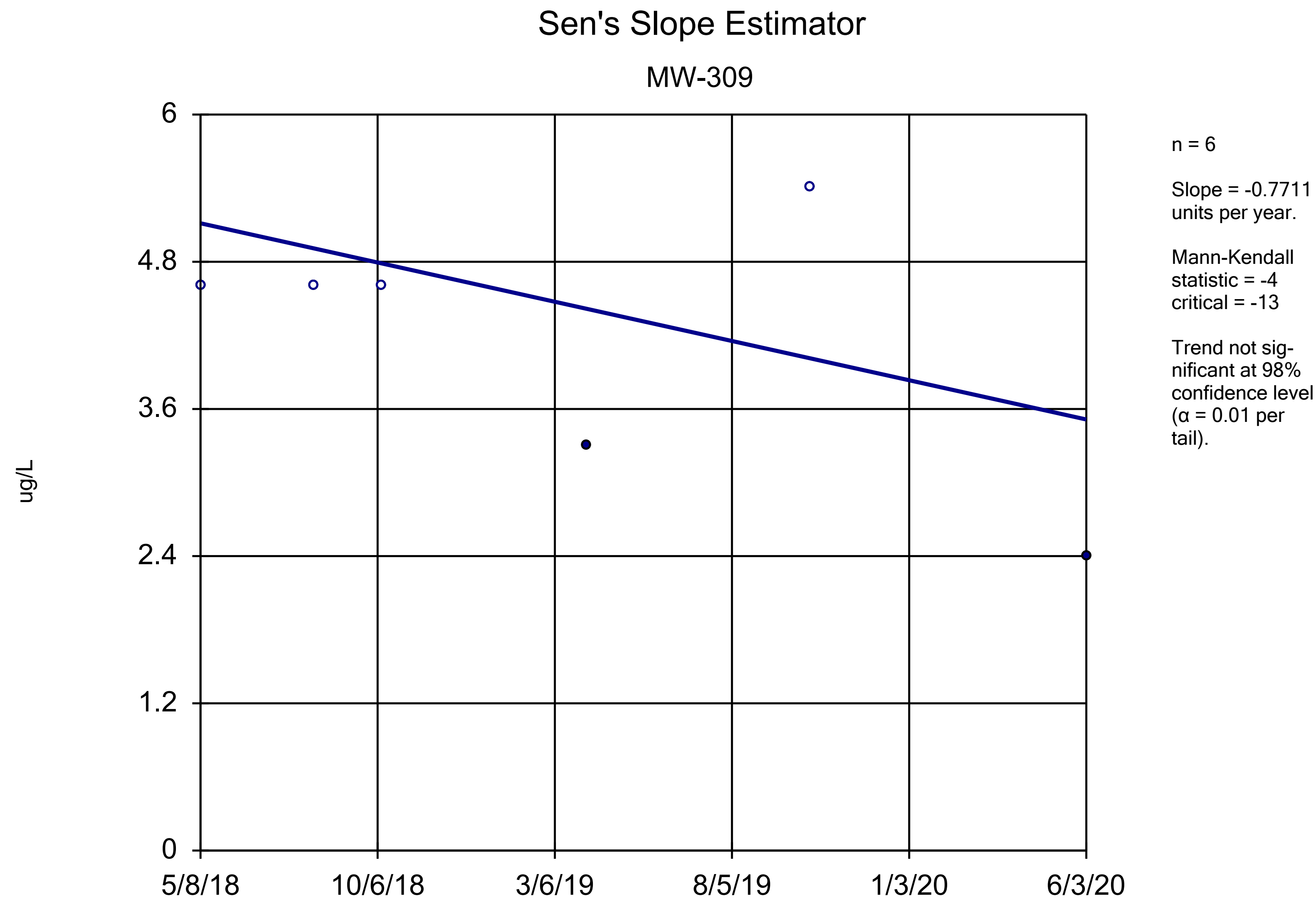
Hollow symbols indicate censored values.



Constituent: Lithium   Analysis Run 11/21/2020 5:57 PM

Burlington Generating Station   Client: SCS Engineers   Data: BGS_Export_201121_Rev

11/25/2020 - Classification: Internal - ECRM7803923

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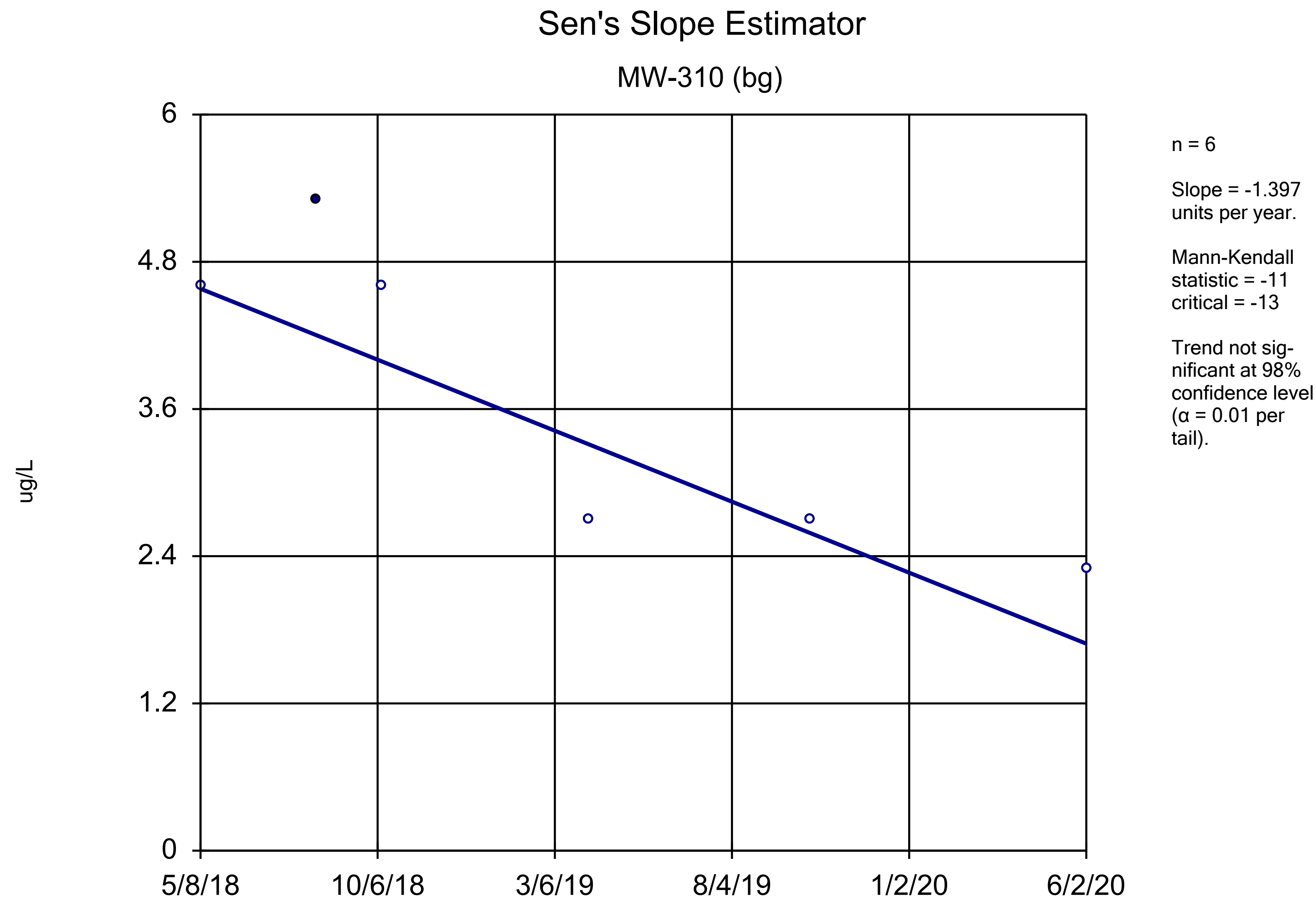
Hollow symbols indicate censored values.



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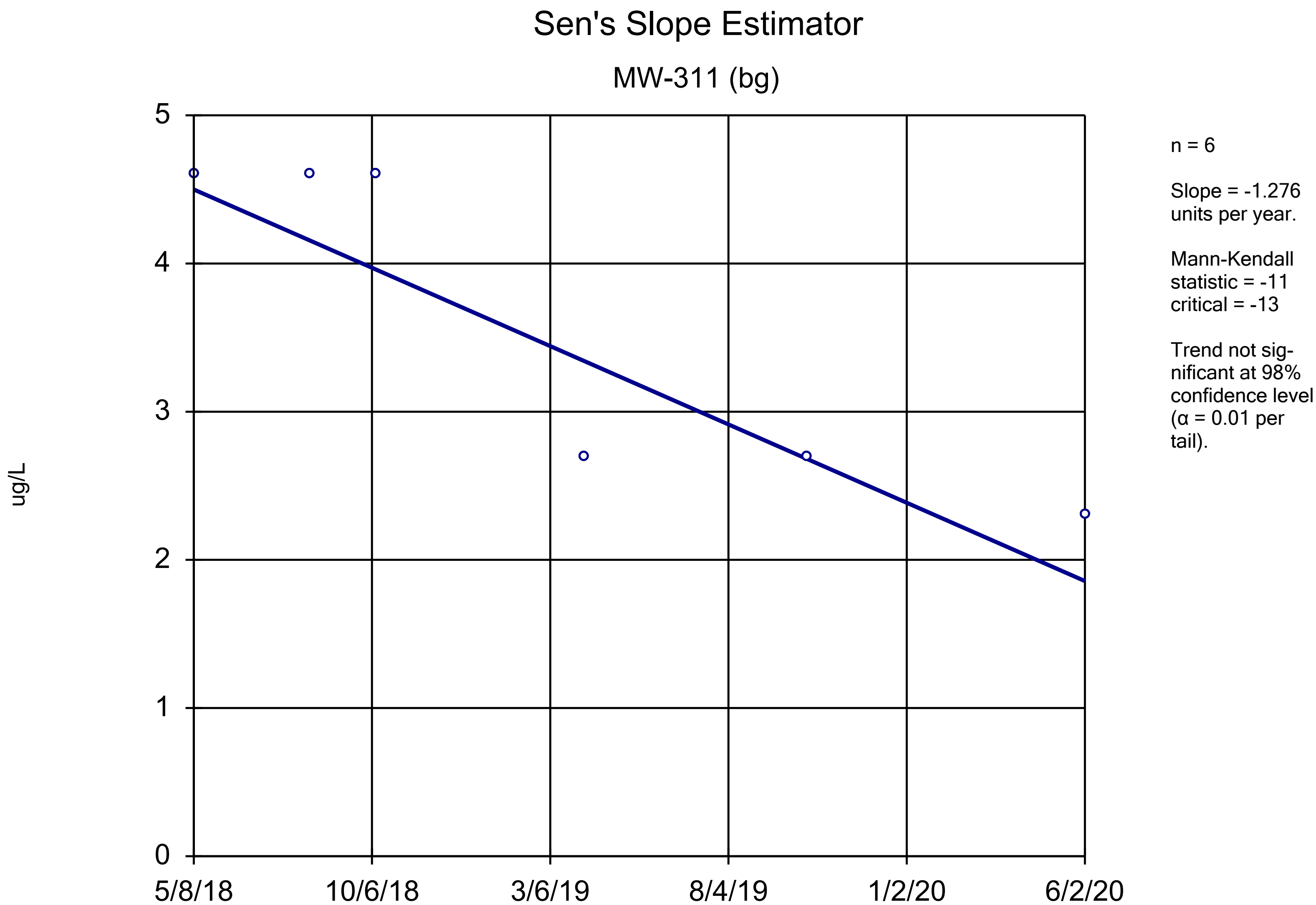
Hollow symbols indicate censored values.



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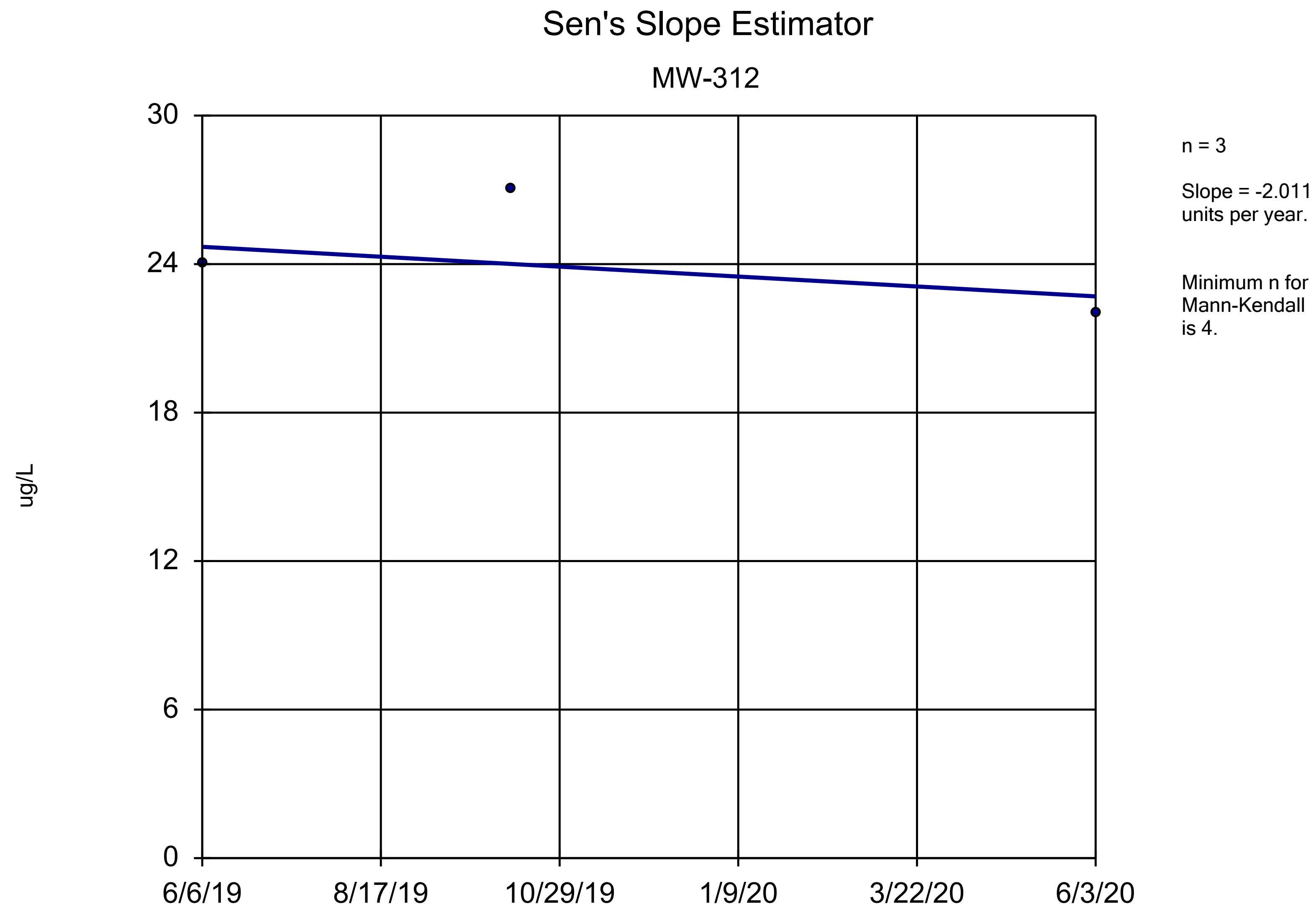
11/25/2020 - Classification: Internal - ECRM7803923



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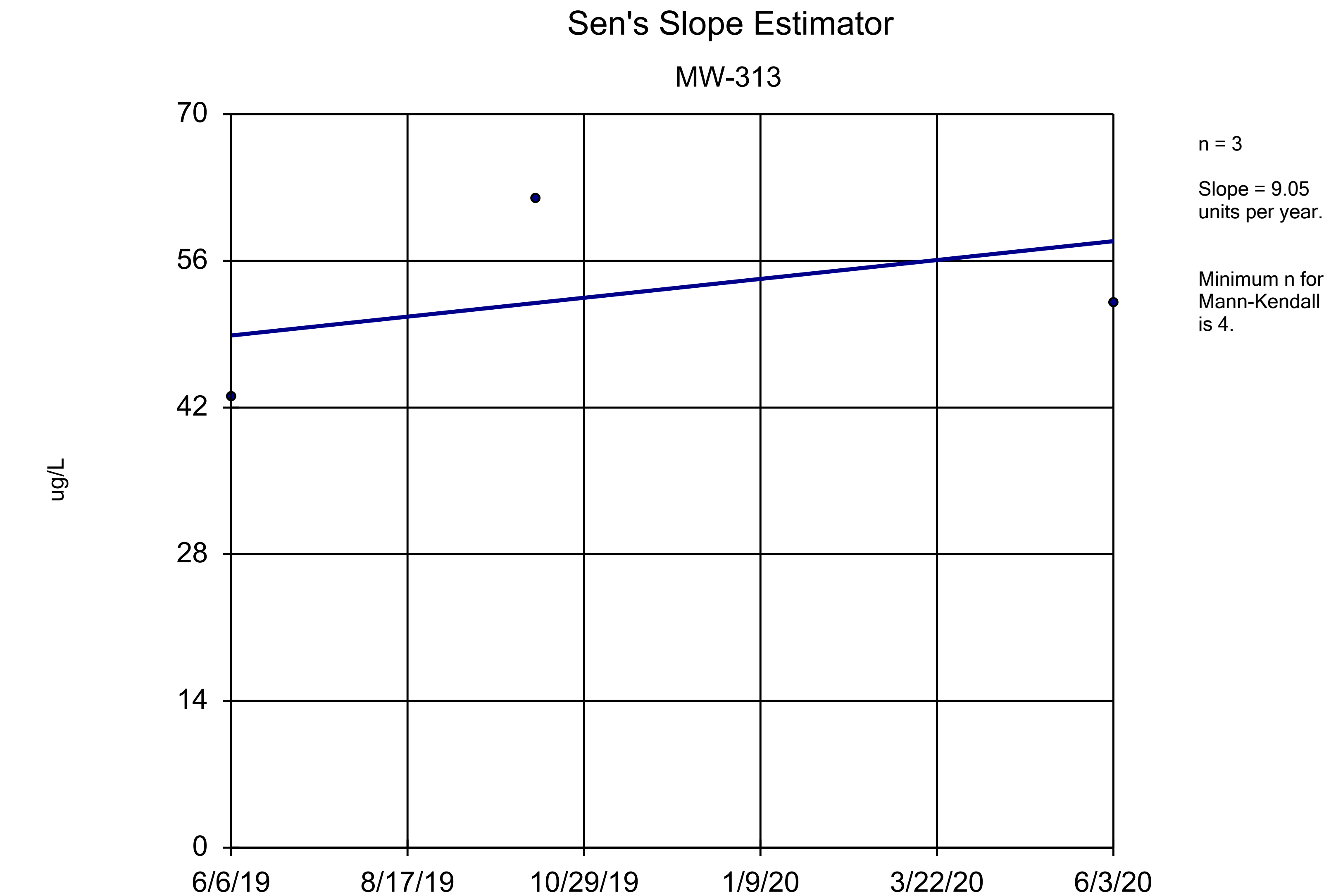

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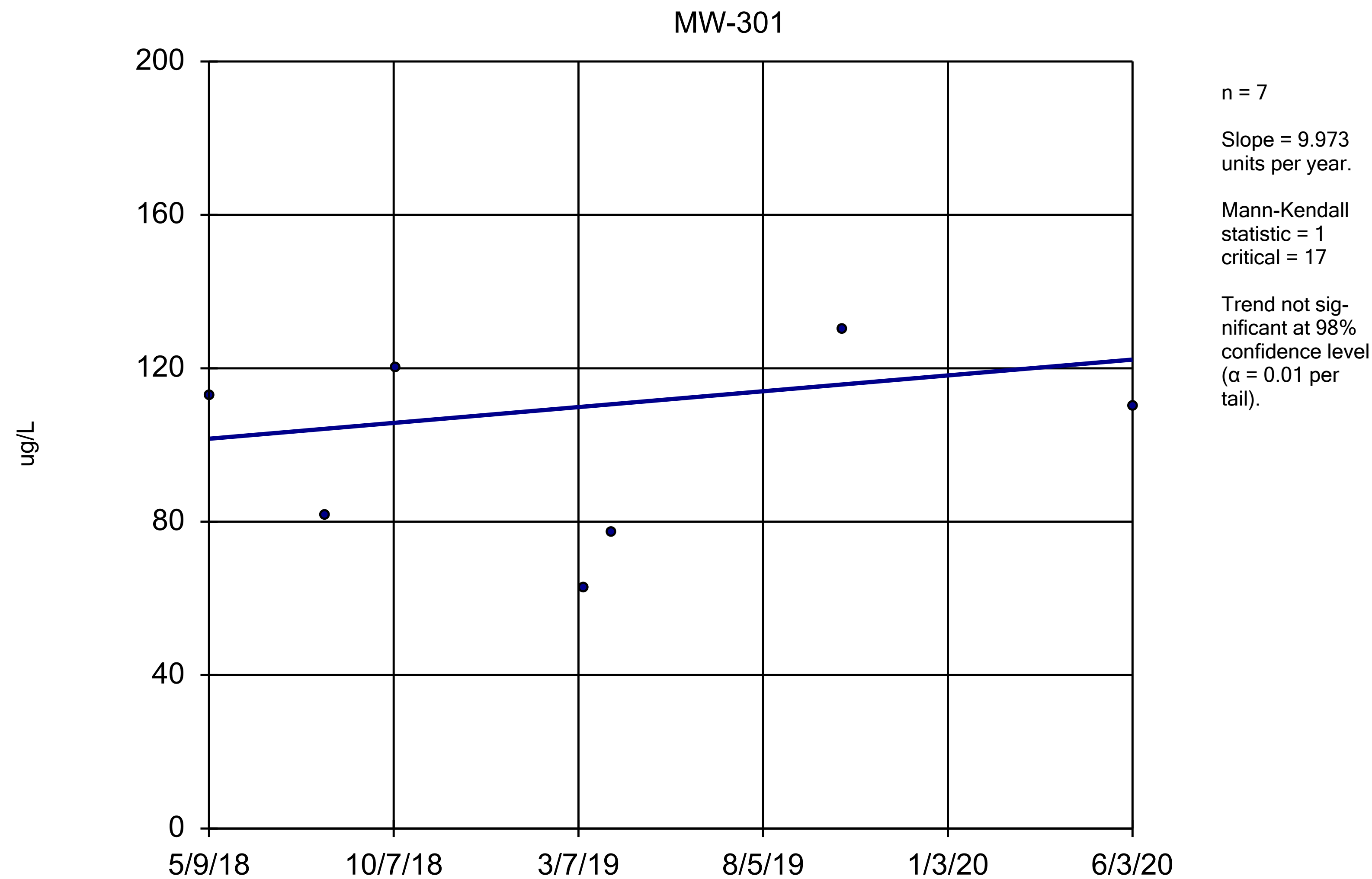
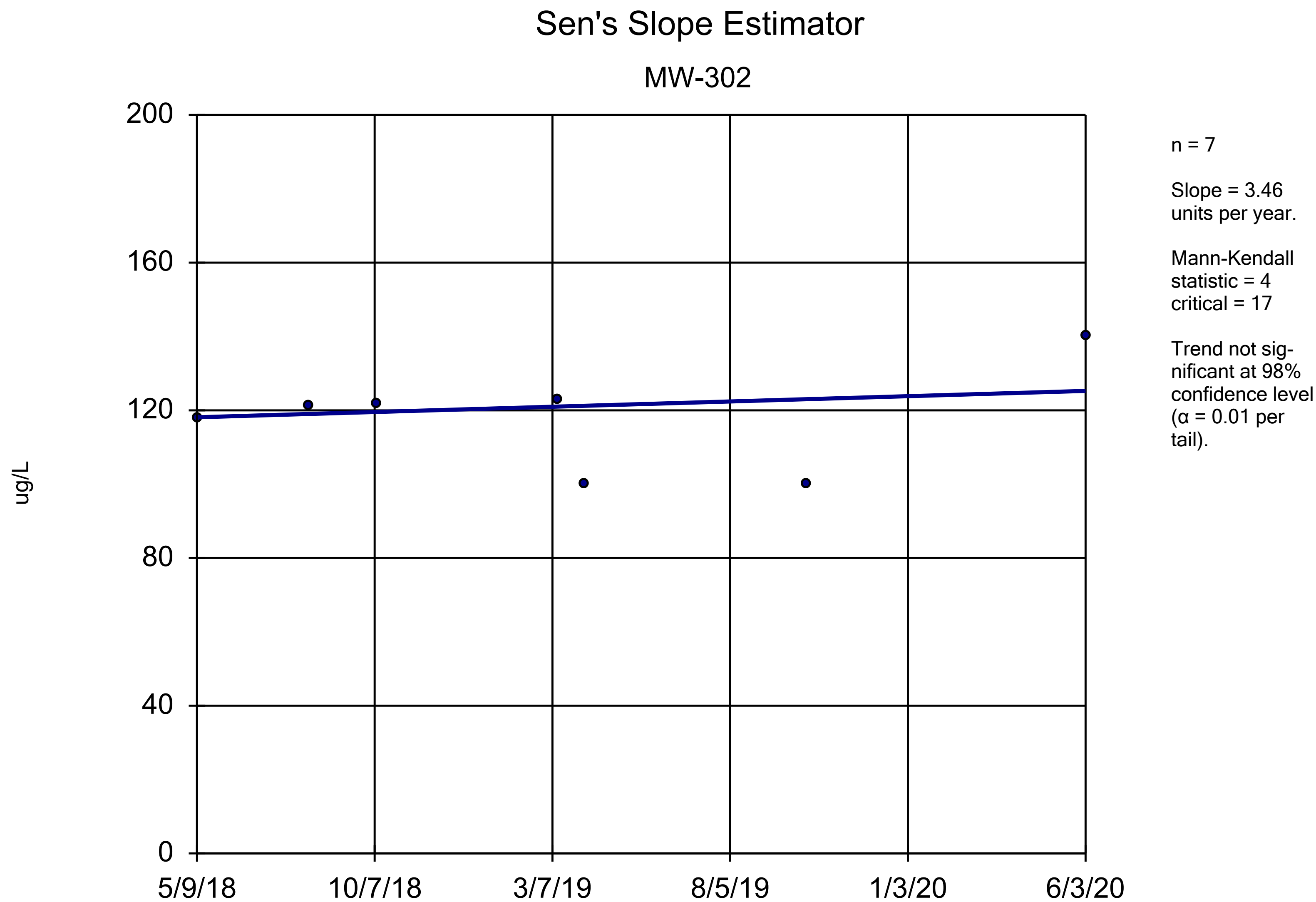
Burlington Generating Station   Client: SCS Engineers   Data: BGS_Export_201121_Rev

Sen's Slope Estimator



Constituent: Molybdenum Analysis Run 11/21/2020 5:58 PM

Burlington Generating Station Client: SCS Engineers Data: BGS_Export_201121_Rev



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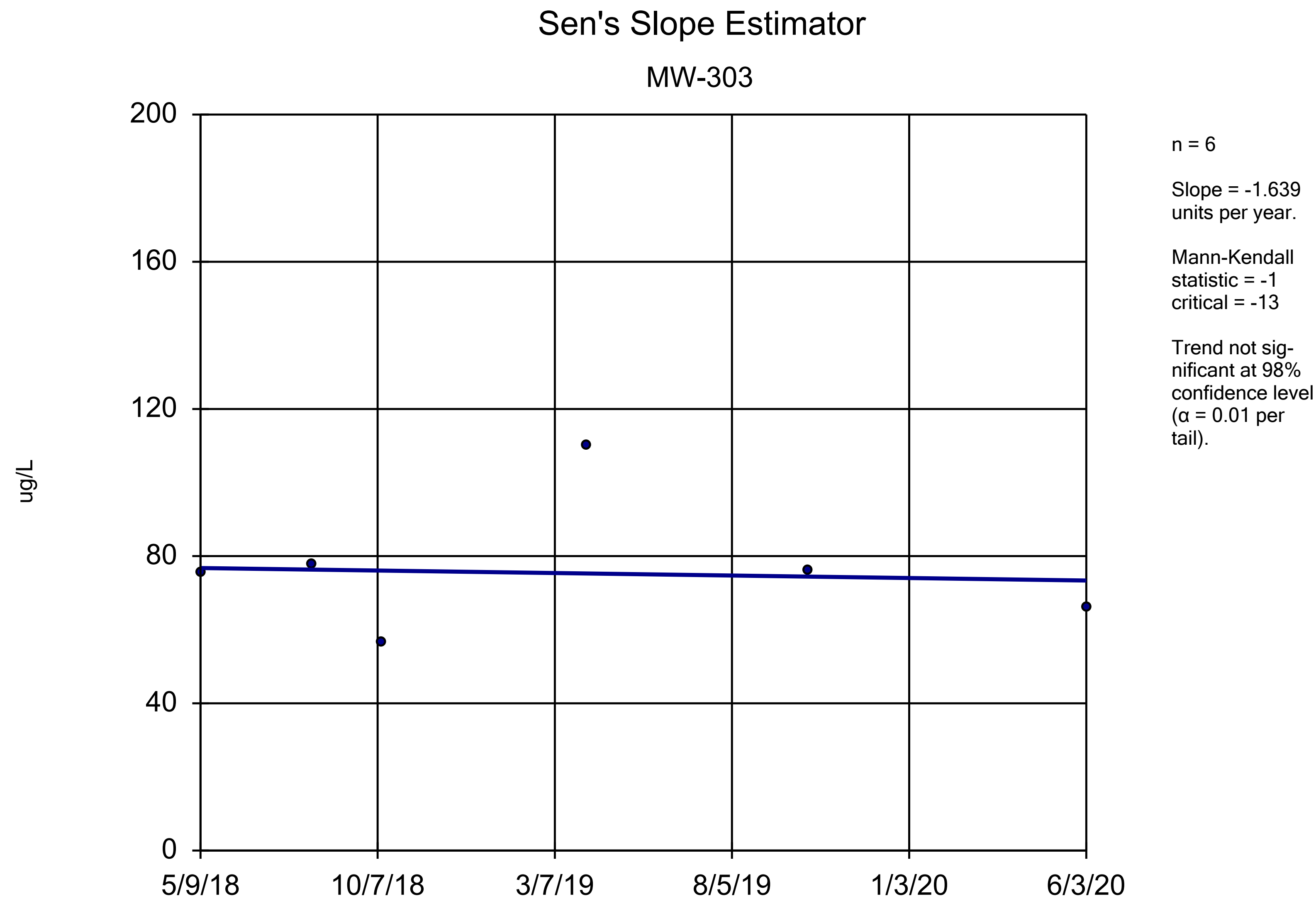

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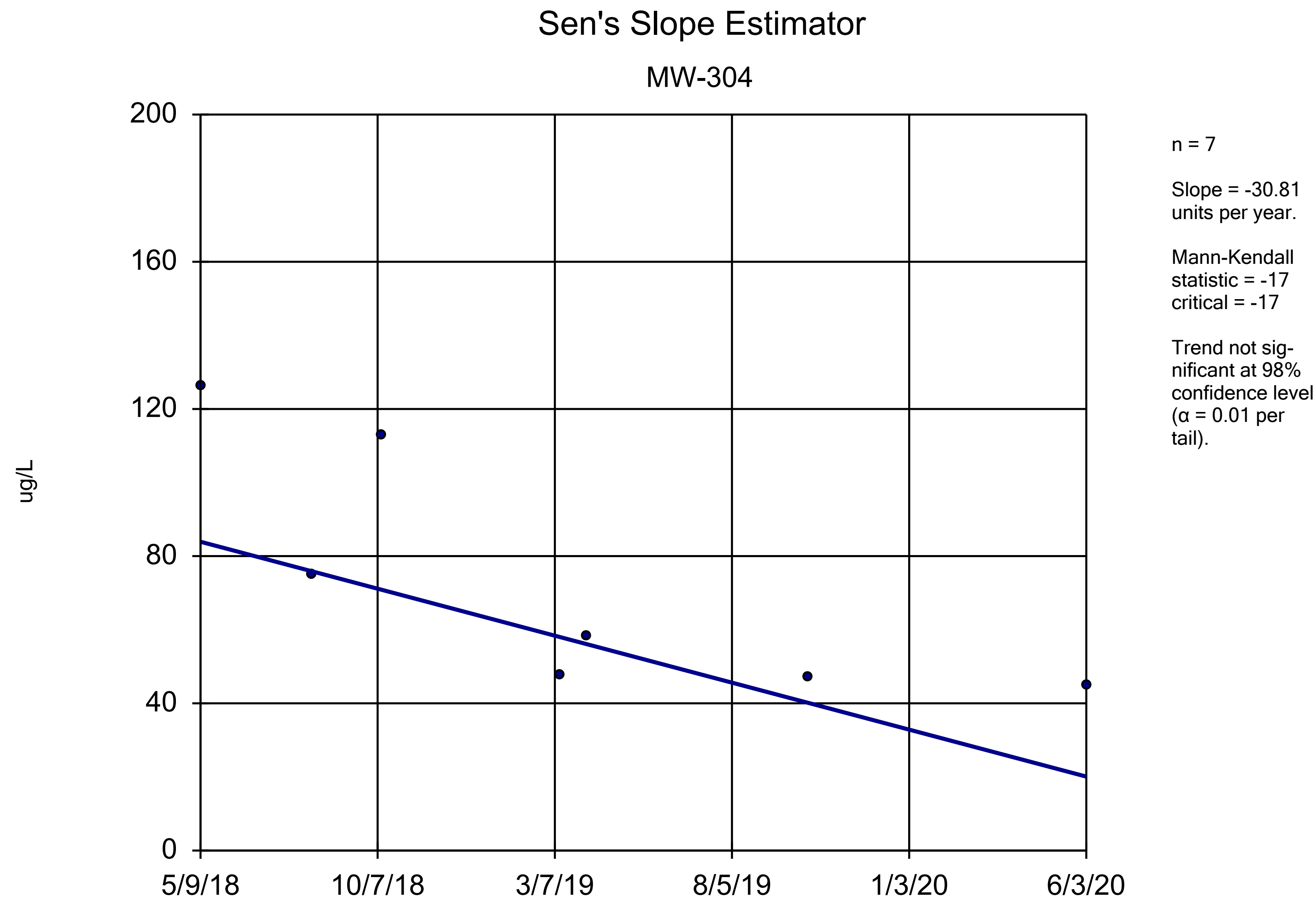
11/25/2020 - Classification: Internal - ECRM7803923



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Burlington Generating Station Client: SCS Engineers Data: BGS_Export_201121_Rev

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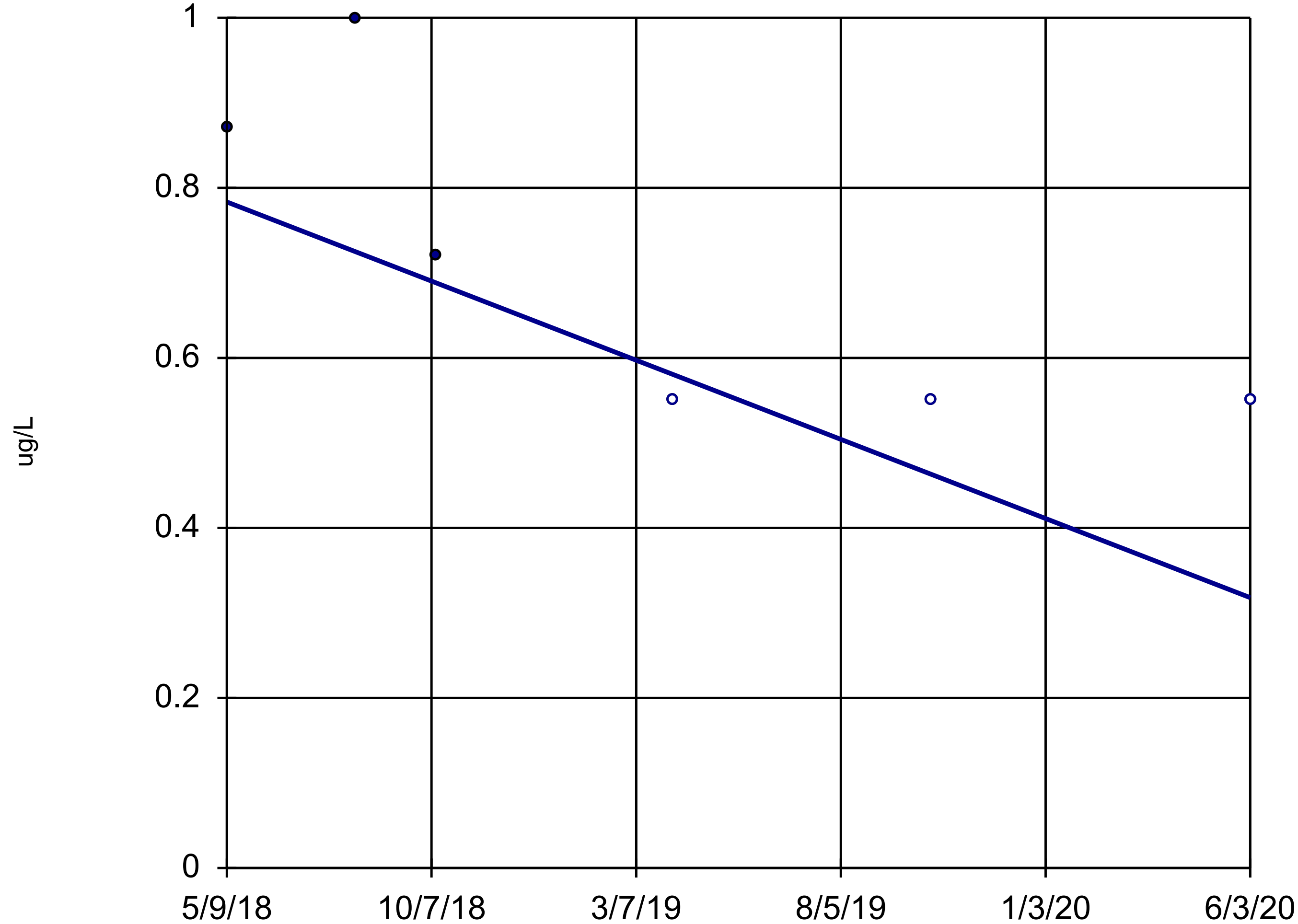
Hollow symbols indicate censored values.

Sen's Slope Estimator

MW-305



n = 6

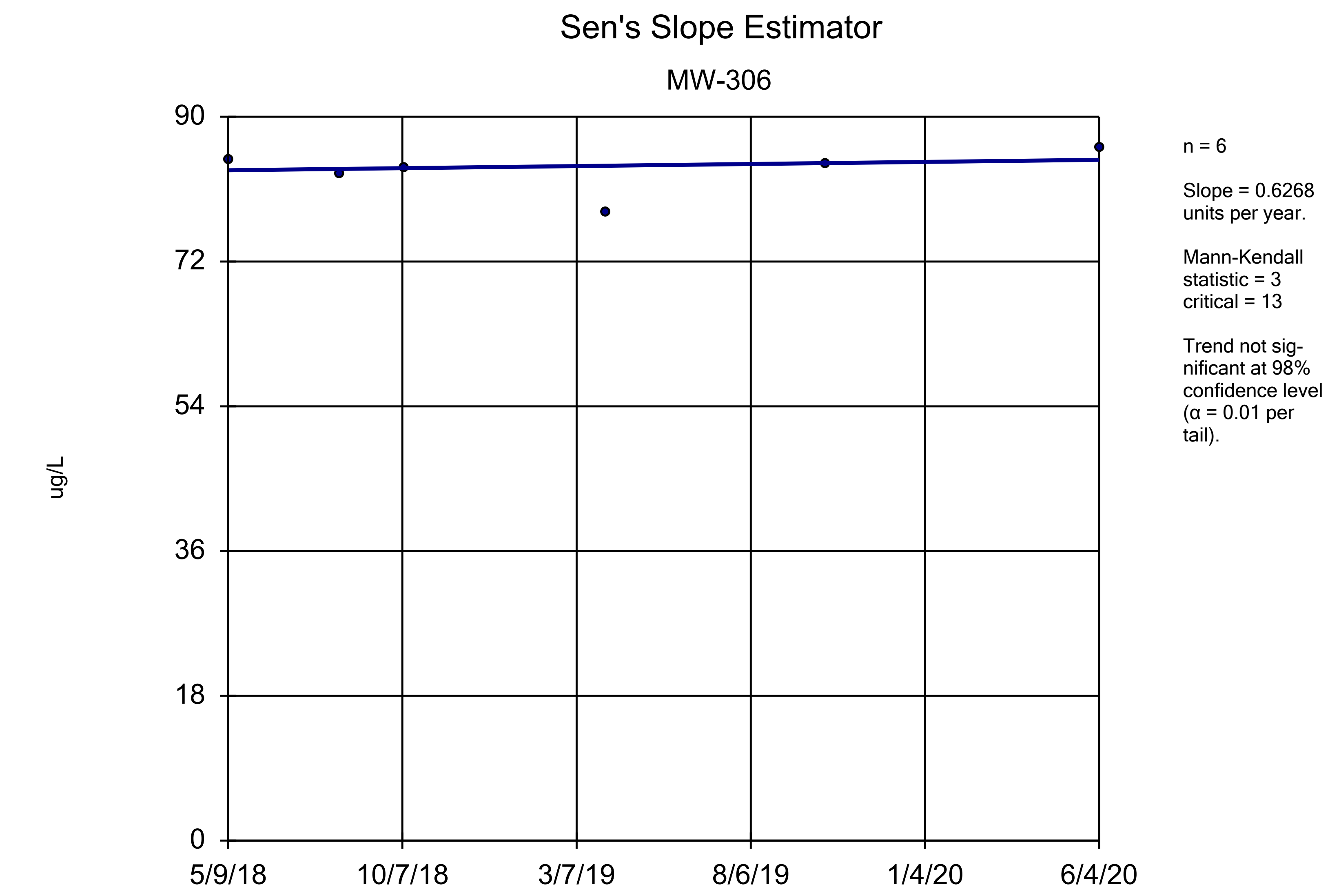
Slope = -0.2246 units per year.

Mann-Kendall statistic = -10 critical = -13

Trend not significant at 98% confidence level (α = 0.01 per tail).

Constituent: Molybdenum   Analysis Run 11/21/2020 5:58 PM

Burlington Generating Station   Client: SCS Engineers   Data: BGS_Export_201121_Rev



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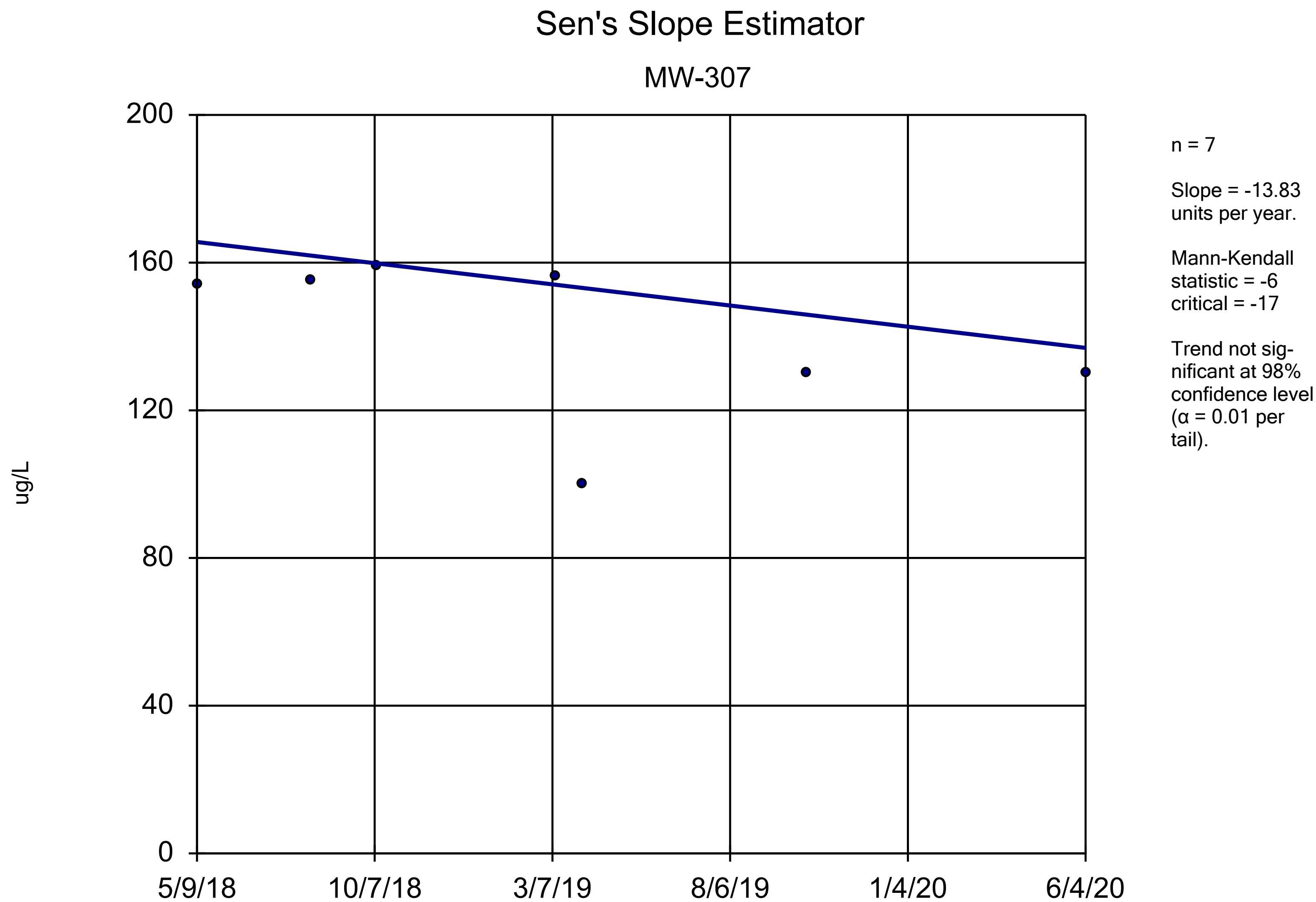
Burlington Generating Station Client: SCS Engineers Data: BGS_Export_201121_Rev

Sanitas™ v.9.6.27 Software licensed to SCS Engineers. UG



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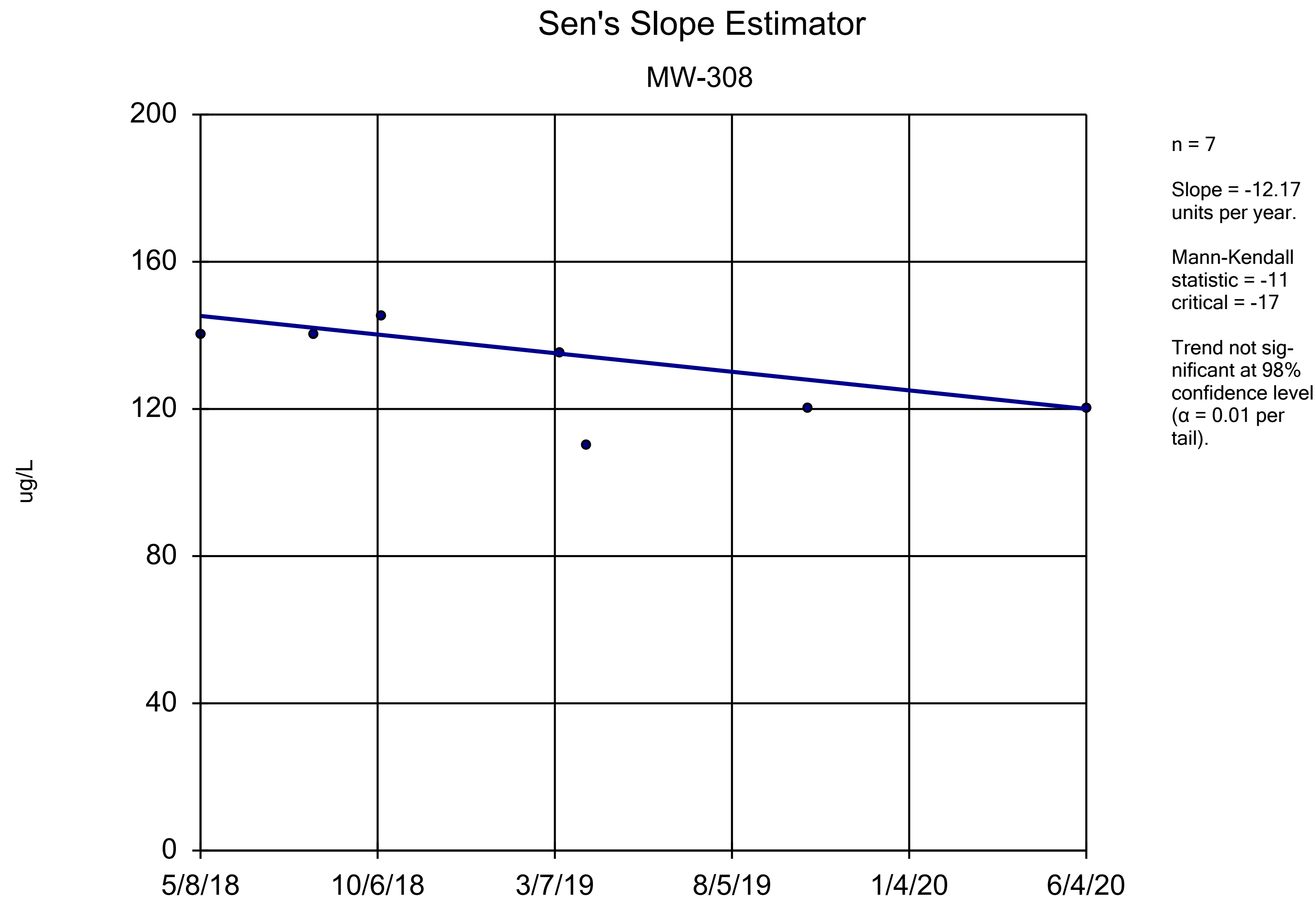
Burlington Generating Station   Client: SCS Engineers   Data: BGS_Export_201121_Rev



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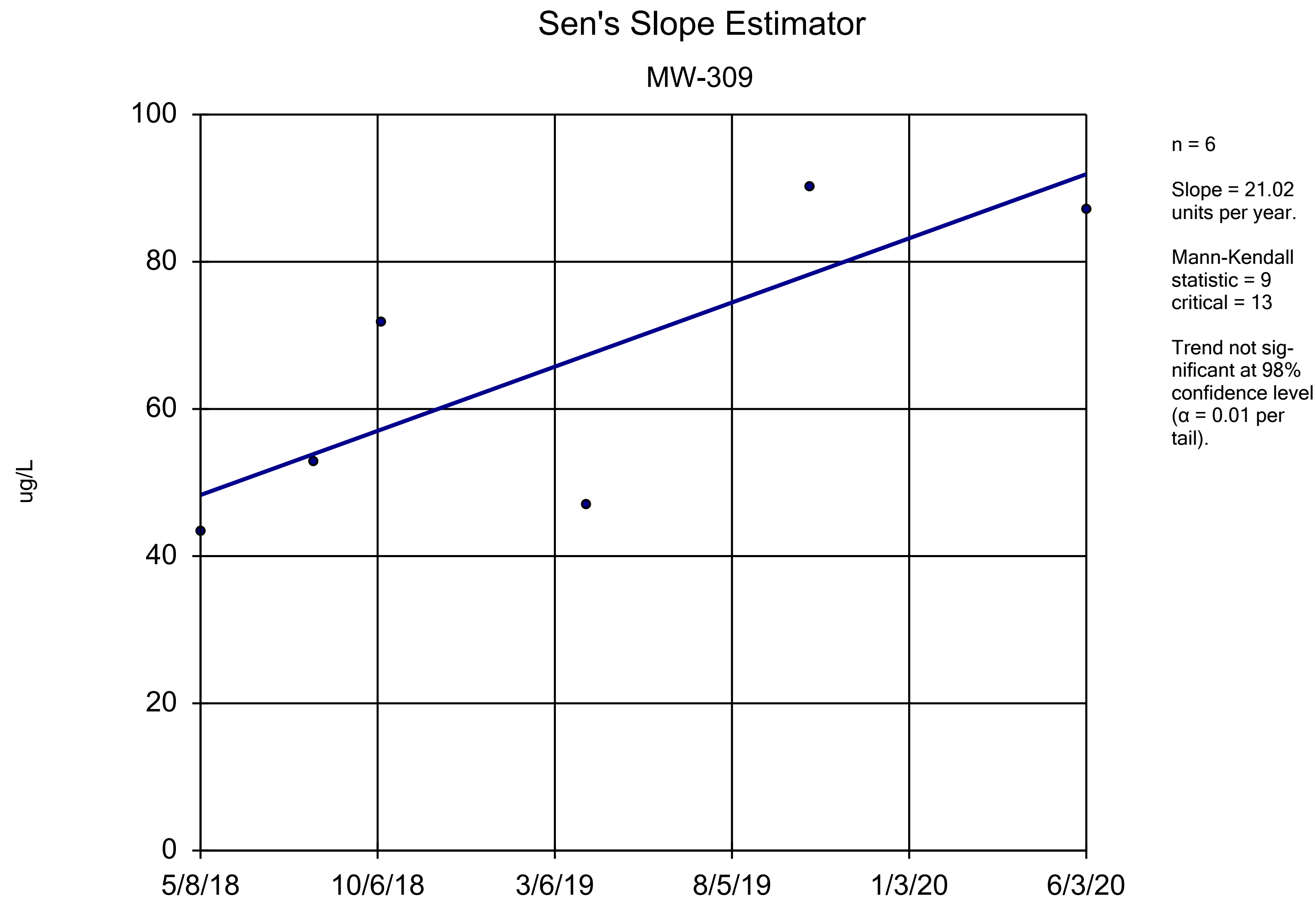

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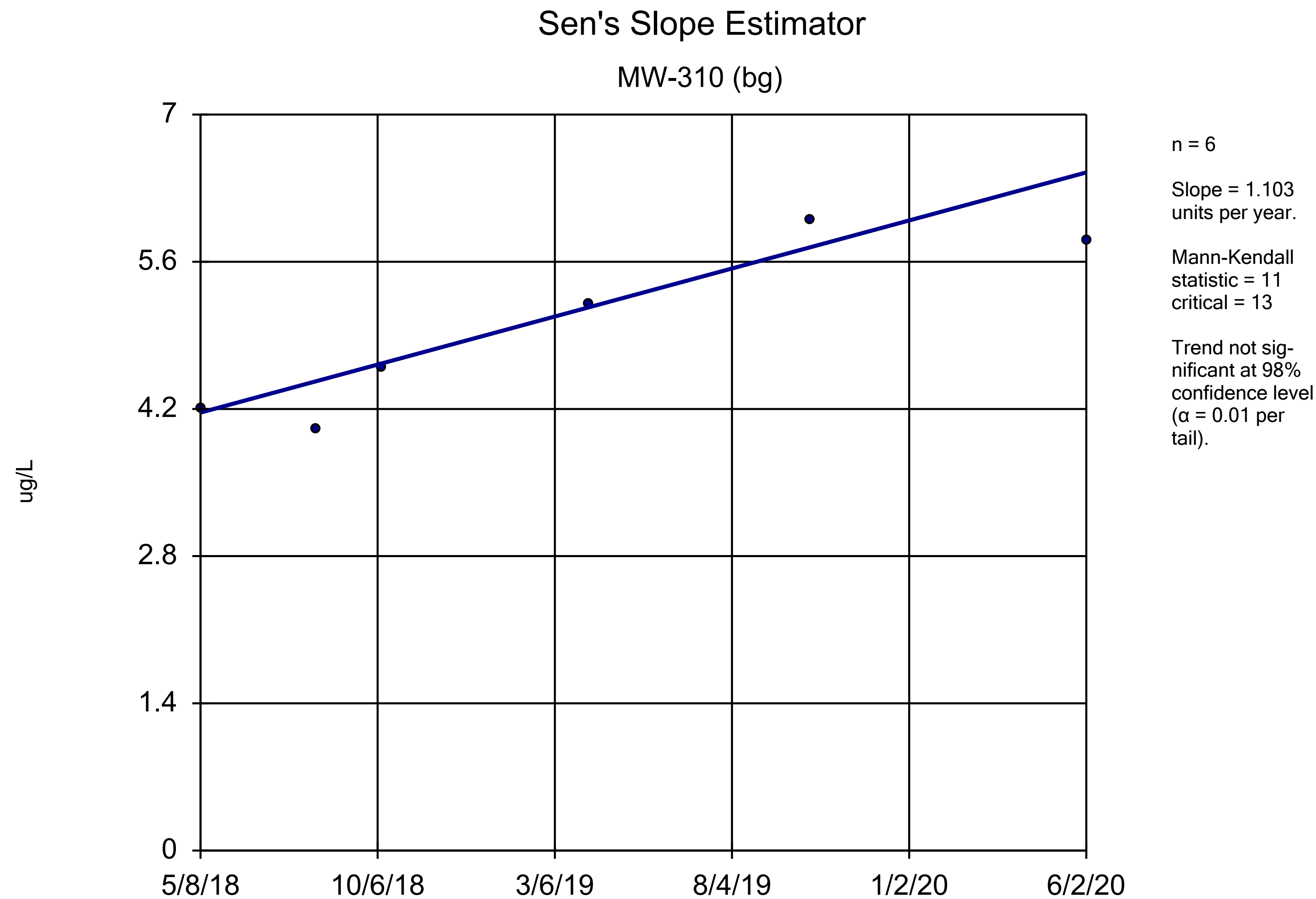

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Burlington Generating Station Client: SCS Engineers Data: BGS_Export_201121_Rev

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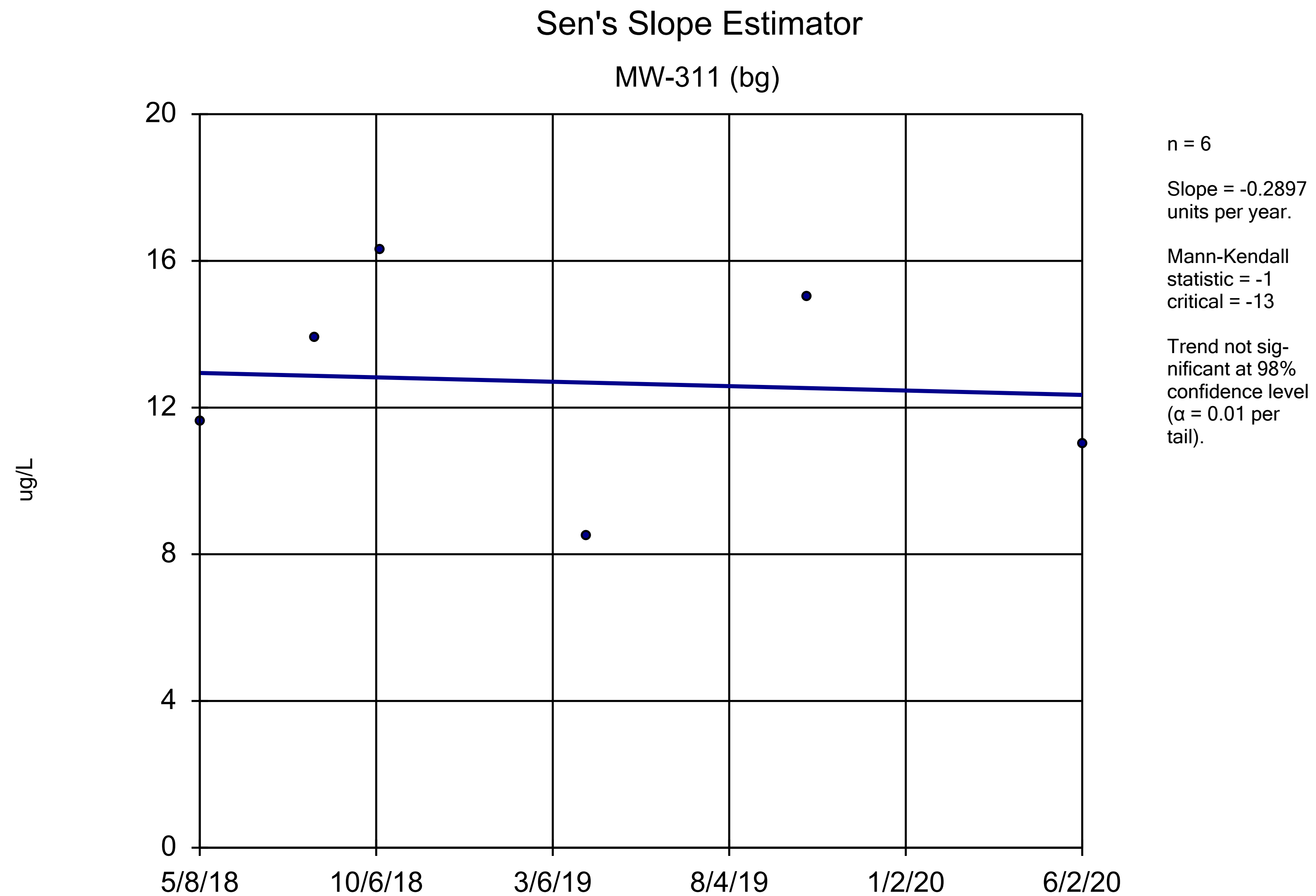

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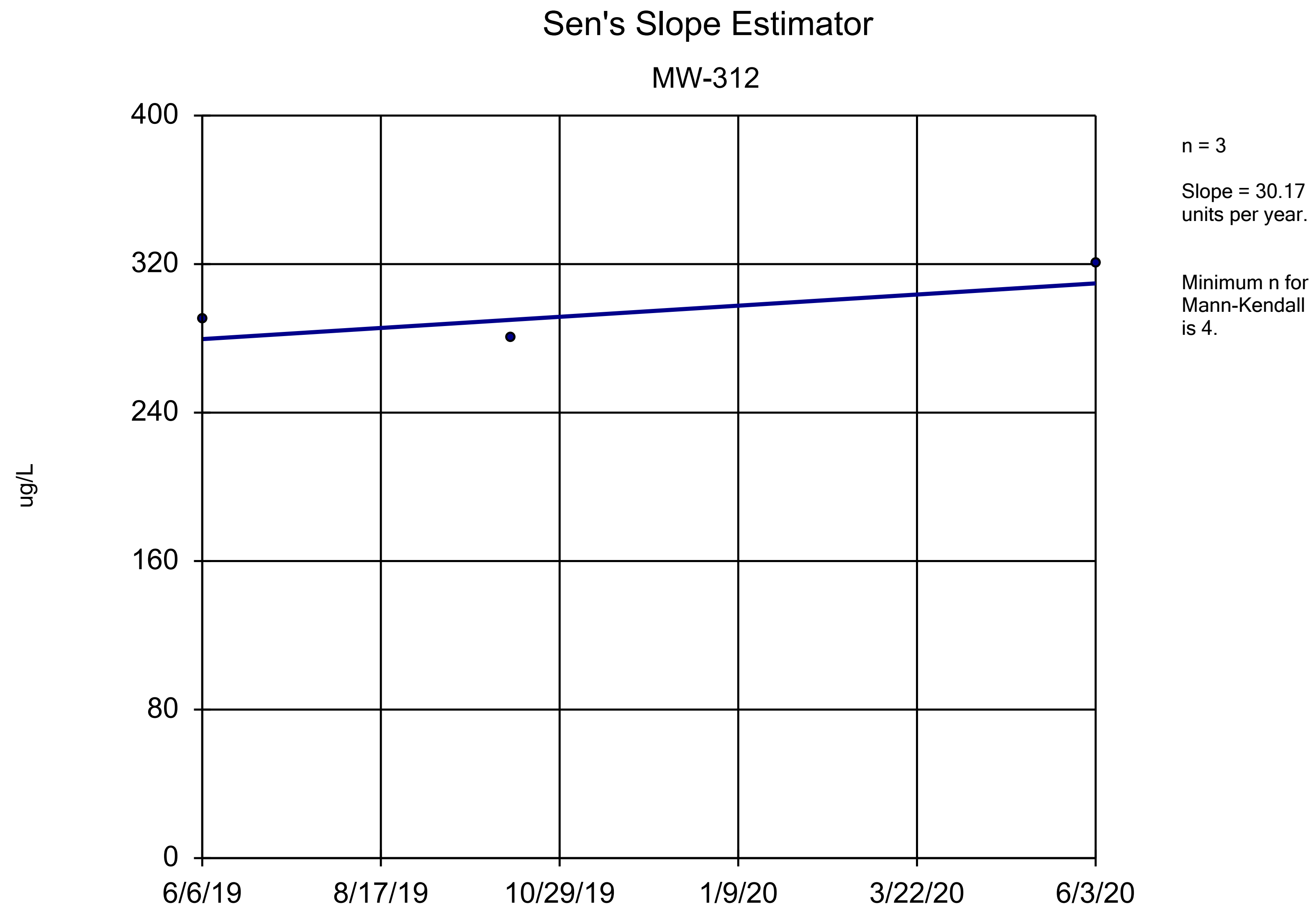

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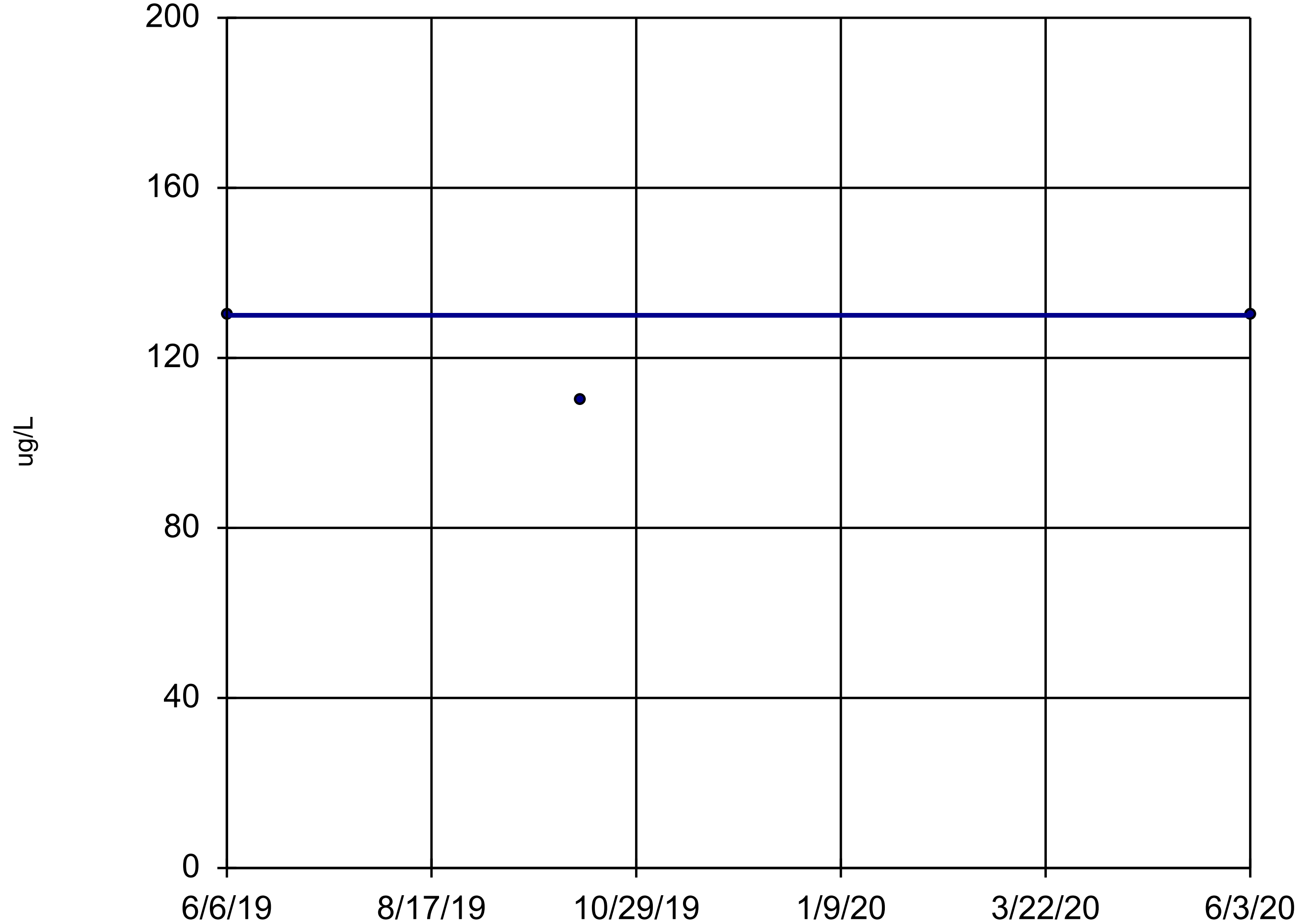
Burlington Generating Station Client: SCS Engineers Data: BGS_Export_201121_Rev

Sanitas™ v.9.6.27 Software licensed to SCS Engineers. UG

Sen's Slope Estimator

MW-313



n = 3

Slope = 0
units per year.

Minimum n for
Mann-Kendall
is 4.

Constituent: Molybdenum Analysis Run 11/21/2020 5:58 PM

Burlington Generating Station Client: SCS Engineers Data: BGS_Export_201121_Rev

Appendix D

Selection of Remedy Semiannual Reports

Semiannual Progress Report Selection of Remedy – Burlington Generating Station

Burlington Generating Station
Burlington, Iowa

Prepared for:

Alliant Energy

SCS ENGINEERS

25220081.00 | March 13, 2020

2830 Dairy Drive
Madison, WI 53718-6751
608-224-2830

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Tables

Figures

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1.0 INTRODUCTION AND PURPOSE

The Semiannual Progress Report for remedy selection at the Interstate Power and Light Company (IPL) Burlington Generating Station (BGS) was prepared to comply with U.S. Environmental Protection Agency (USEPA) regulations regarding the Disposal of Coal Combustion Residuals (CCR) from Electric Utilities [40 CFR 257.50-107], or the "CCR Rule" (Rule). Specifically, the selection of remedy process was initiated to fulfill the requirements of 40 CFR 257.97.

1.1 BACKGROUND

The Assessment of Corrective Measures (ACM) for the four BGS CCR units was completed on September 12, 2019. The ACM was completed in response to the detection of lithium and molybdenum at statistically significant levels above the Groundwater Protection Standard (GPS) in groundwater samples from downgradient monitoring wells. Lithium concentrations exceeded the GPS at the following downgradient monitoring wells: MW-302, MW-303, MW-307, and MW-308. Molybdenum concentrations exceeded the GPS at the following downgradient monitoring wells: MW-302, MW-307, and MW-308.

This Semiannual Progress Report summarizes data collected and remedy evaluation progress made since the ACM was completed in September 2019, and outlines planned future activities to complete the selection of remedy process.

1.2 SITE INFORMATION AND MAPS

BGS is located along the west bank of the Mississippi River, about 5 miles south of the City of Burlington, in Des Moines County, Iowa (**Figure 1**). The address of the generating station is 4282 Sullivan Slough Road, Burlington, Iowa. In addition to the coal-fired generating station, the property also contains a coal stockpile, diesel-fueled combustion turbines, hydrated fly ash storage area, upper ash pond, lower pond, economizer ash pond, bottom ash pond, and ash seal pond.

The four CCR units at the facility (upper ash pond, economizer ash pond, bottom ash pond, and ash seal pond) are monitored with a multi-unit groundwater monitoring system and are the subject of this Semiannual Progress Report. A map showing the CCR units and all background (or upgradient) and downgradient monitoring wells with identification numbers for the CCR groundwater monitoring program is provided as **Figure 2**.

Groundwater flow at the site is generally to the south-southeast, and the groundwater flow direction and water levels fluctuate seasonally due to the proximity to the river. Depth to groundwater as measured in the site monitoring wells varies from less than 1 to 15 feet below ground surface due to topographic variations across the facility and seasonal variations in water levels.

2.0 SUMMARY OF WORK COMPLETED

Work completed to support remedy selection for the BGS CCR units is summarized in **Table 1**. Activities completed within the 6-month period covered by this semiannual report are discussed in more detail below.

2.1 MONITORING NETWORK CHANGES

Planning, permitting, and access coordination for four additional monitoring wells is in progress. As of March 9, 2020, IPL has received the necessary federal, state, and local approvals for the well installations. The proposed wells are deeper piezometers, to be located adjacent to existing monitoring wells MW-302, MW-307, MW-310, and MW-313. The locations of existing monitoring wells at BGS are shown on **Figure 2**.

2.2 GROUNDWATER MONITORING

Groundwater samples were collected in October 2019. The October 2019 monitoring event was part of the routine semiannual assessment monitoring program. The wells sampled included the 11 wells in the original monitoring system (MW-301 through MW-311) and the two additional wells (MW-312 and MW-313) installed in May 2019. A summary of groundwater samples collected since submittal of the ACM is provided in **Table 2**.

2.3 GEOTECHNICAL INVESTIGATION

A geotechnical field investigation, which included the advancement of soil borings and the collection of soil and CCR samples, was performed at BGS in December 2019 through January 2020. The purpose of the geotechnical investigation work is to supplement the existing information and enhance knowledge of:

- CCR depths, elevations, and volumes
- Spatial variation and physical properties of CCR and site soils
- Water level conditions in CCR and site soils

This additional geotechnical data will assist Alliant with:

- Characterization of the site and potential source areas
- Evaluation of corrective measure alternatives
- CCR impoundment closure design and construction

2.4 EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

A qualitative assessment of potential Corrective Measure Alternatives using the selection criteria in 40 CFR 257.97(b) and (c) was provided in the September 2019 ACM. **Table 3** summarizes the assessment completed for the ACM. No updates or changes to the assessment have been made based on additional information obtained since the issue of the ACM. Additional groundwater data collection and analysis is necessary for the evaluation of the monitored natural attenuation (MNA) option. Updates to the assessment, and development of the quantitative evaluation system discussed in the ACM, will be completed in the future based on updates to the conceptual site model, delineation of the nature and extent of impacts, and collection of additional data relevant to remedy selection.

3.0 PLANNED ACTIVITIES

Planned activities related to the remedy selection process include the following:

- Install four piezometers nested with existing monitoring wells MW-302, MW-307, MW-310, and MW-313. The piezometers will provide additional data on vertical groundwater flow and groundwater constituent concentrations.

- Collect groundwater samples at the four new piezometers.

- Continue semiannual assessment monitoring for the existing monitoring well network and new monitoring wells.

- Evaluate MNA feasibility, including additional evaluation of groundwater flow and groundwater quality.

- Update conceptual site model based on findings of nature and extent investigation.

- Continue evaluation of remedial options.

- Conduct public meeting (40 CFR 257.96(e)).

Tables

Table 1. Timeline for Completed Work - Selection of Remedy
Burlington Generating Station / SCS Engineers Project #25220081.00

Date	Activity
May 2019	Additional monitoring wells installed to investigate nature and extent (MW-312 and MW-313)
June 2019	Sampled new monitoring wells (MW-312 and MW-313)
September 2019	Completed the Well Documentation Report for the new wells
September 2019	Completed ACM
October 2019	Conducted semiannual assessment monitoring event, including second round of sampling for the new wells (MW-312 and MW-313)
January 2020	Completed Statistical Evaluation of October 2019 groundwater monitoring results
January 2020	Completed 2019 Annual Groundwater Monitoring and Corrective Action Report
November 2019 to spring 2020	Planning, permitting, and access arrangements for installation of four additional monitoring wells (piezometers) to investigate the vertical extent of impacts
December 2019/ January 2020	Execute source area and geotechncial field investigation

Created by: NDK Date: 2/19/2020
Last revision by: MDB Date: 2/26/2020
Checked by: TK Date: 2/26/2020

I:\25220081.00\Deliverables\2020 Semiannual - Selection Remedy\Tables\[Table 1_Timeline_SOR_BGS.xlsx]Timeline

Table 2. Groundwater Samples Summary - Events Since ACM Submittal
Burlington Generating Station / SCS Engineers Project #252220081.00

Sample Dates	Downgradient Wells											Background Wells	
	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306	MW-307	MW-308	MW-309	MW-312	MW-313	MW-310	MW-311
10/10-11/2019	A	A	A	A	A	A	A	A	A	A	A	A	A
Total Samples	1	1	1	1	1	1	1	1	1	1	1	1	1

Abbreviation:
A = Required by Assessment Monitoring Program

Created by: NDK Date: 2/19/2020
Last revision by: NDK Date: 2/19/2020
Checked by: MDB Date: 2/19/2020

I:\25220081.00\Deliverables\2020 Semiannual - Selection Remedy\Tables\[Table 2_GW_Samples_Summary_Table_BGS.xlsx]GW Summary

Table 3. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25220081.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill
CORRECTIVE ACTION ASSESSMENT - 40 CFR 257.97(b)					
257.97(b)(1) Is remedy protective of human health and the environment?	No	Yes	Yes	Yes	Yes
257.97(b)(2) Can the remedy attain the groundwater protection standard?	Unlikely	Yes	Yes	Yes	Yes
257.97(b)(3) Can the remedy control the source(s) of releases so as to reduce or eliminate, to the maximum extent feasible, further releases of constituents in appendix IV to this part into the environment?	No	Yes	Yes	Yes	Yes
257.97(b)(4) Can the remedy remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible?	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR
257.97(b)(5) Can the remedy comply with standards for management of wastes as specified in §257.98(d)?	Not Applicable	Yes	Yes	Yes	Yes
LONG- AND SHORT-TERM EFFECTIVENESS - 40 CFR 257.97(c)(1)					
257.97(c)(1)(i) Magnitude of reduction of existing risks	No reduction of existing risk	Existing risk reduced by achieving GPS	Same as Alternative #2	Same as Alternative #2	Same as Alternative #2
257.97(c)(1)(ii) Magnitude of residual risks in terms of likelihood of further releases due to CCR remaining following implementation of a remedy	No reduction of existing risk. Residual risk is limited for all alternatives due to limited extent of impacts and lack of receptors.	Magnitude of residual risk of further releases is lower than current conditions due to final cover eliminating infiltration through CCR; Residual risk is limited for all alternatives due to limited extent of impacts and lack of receptors	Same as Alternative #2 with potential further reduction in release risk due to CCR material footprint; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts	Same as Alternative #3 with potential further reduction in release risk due to composite liner and cover; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts	Same as Alternative #3 with potential further reduction in release risk due to removal of CCR from site; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts
257.97(c)(1)(iii) The type and degree of long-term management required, including monitoring, operation, and maintenance	Not Applicable	30-year post-closure groundwater monitoring; Groundwater monitoring network maintenance and as-needed repair/replacement; Final cover maintenance (e.g., mowing and as-needed repair); Periodic final cover inspections; Additional corrective action as required based on post-closure groundwater monitoring	Same as Alternative #2	Same as Alternative #2	No on-site long-term management required; Limited on-site post-closure groundwater monitoring until GPS are achieved; Receiving disposal facility will have same/similar long-term monitoring, operation, and maintenance requirements as Alternative #2

Table 3. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25220081.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill
LONG- AND SHORT-TERM EFFECTIVENESS - 40 CFR 257.97(c)(1) (continued)					
257.97(c)(1)(iv) Short-term risks - Implementation					
Excavation	None	Limited risk to community and environment due to limited amount of excavation (<100K cy) required to establish final cover subgrades and no off-site excavation	Same as Alternative #2 with increased risk to environment due to increased excavation volumes (>100K cy, <300K cy) required for consolidation	Same as Alternative #3 with increased risk to environment due to increased excavation volumes (>1M cy) and temporary CCR storage during disposal site construction required for removal and on-site re-disposal	Same as Alternative #4 with reduced risk to environment from excavation due to limited on-site storage
Transportation	None	No risk to community or environment from off-site CCR transportation; Typical risk due to construction traffic delivering final cover materials to site	Same as Alternative #2 with reduced risk from construction traffic due to reduced final cover material requirements (smaller cap footprint)	Same as Alternative #2 with increased risk from construction traffic due to increased material import requirements (liner and cap construction required)	Highest level of community and environmental risk due to CCR volume export (>1M cy)
Re-Disposal	None	Limited risk to community and environment due to limited volume of CCR re-disposal (<100K cy)	Same as Alternative #2 with increased risk to environment due to increased excavation volumes (>100K cy, <300K cy) required for consolidation	Same as Alternative #3 with increased risk to environment due to increased excavation volumes (>1M cy) and temporary CCR storage during disposal site construction required for removal and on-site re-disposal	Same as Alternative #4 with increased risk to community and environment due to re-disposal of large CCR volume (>1M cy) at another facility; Re-disposal risks are managed by the receiving disposal facility
257.97(c)(1)(v) Time until full protection is achieved	Unknown	To be evaluated further during remedy selection. Closure and capping anticipated by end of 2022. Groundwater protection timeframe to reach GPS potentially 2 to 10 years following closure construction, achievable within 30-year post-closure monitoring period.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential for decrease in time to reach GPS due to consolidation of CCR.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential decrease in time to reach GPS due to source isolation within liner/cover system.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential decrease in time to reach GPS due to impounded CCR source removal.
257.97(c)(1)(vi) Potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, re-disposal, or containment	No change in potential exposure	Potential for exposure is low. Remaining waste is capped.	Same as Alternative #2	Same as Alternative #2	No potential for on-site exposure to remaining waste since no waste remains on site; Risk of potential exposure is transferred to receiving disposal facility and is likely similar to Alternative #2
257.97(c)(1)(vii) Long-term reliability of the engineering and institutional controls	Not Applicable	Long-term reliability of cap is good; Significant industry experience with methods/ controls; Capping is common practice/industry standard for closure in place for remediation and solid waste management	Same as Alternative #2 with potentially increased reliability due to smaller footprint and reduced maintenance	Same as Alternative #3	Success of remedy at BGS does not rely on long-term reliability of engineering or institutional controls; Overall success relies on reliability of the engineering and institutional controls at the receiving facility.
257.97(c)(1)(viii) Potential need for replacement of the remedy	Not Applicable	Limited potential for remedy replacement if maintained; Some potential for remedy enhancement due to residual groundwater impacts following source control	Same as Alternative #2 with reduced potential need for remedy enhancement with consolidated/smaller closure area footprint	Same as Alternative #2 with further reduction in potential need for remedy enhancement composite with liner	No on-site potential for remedy replacement; Limited potential for remedy enhancement due to residual groundwater impacts following source control

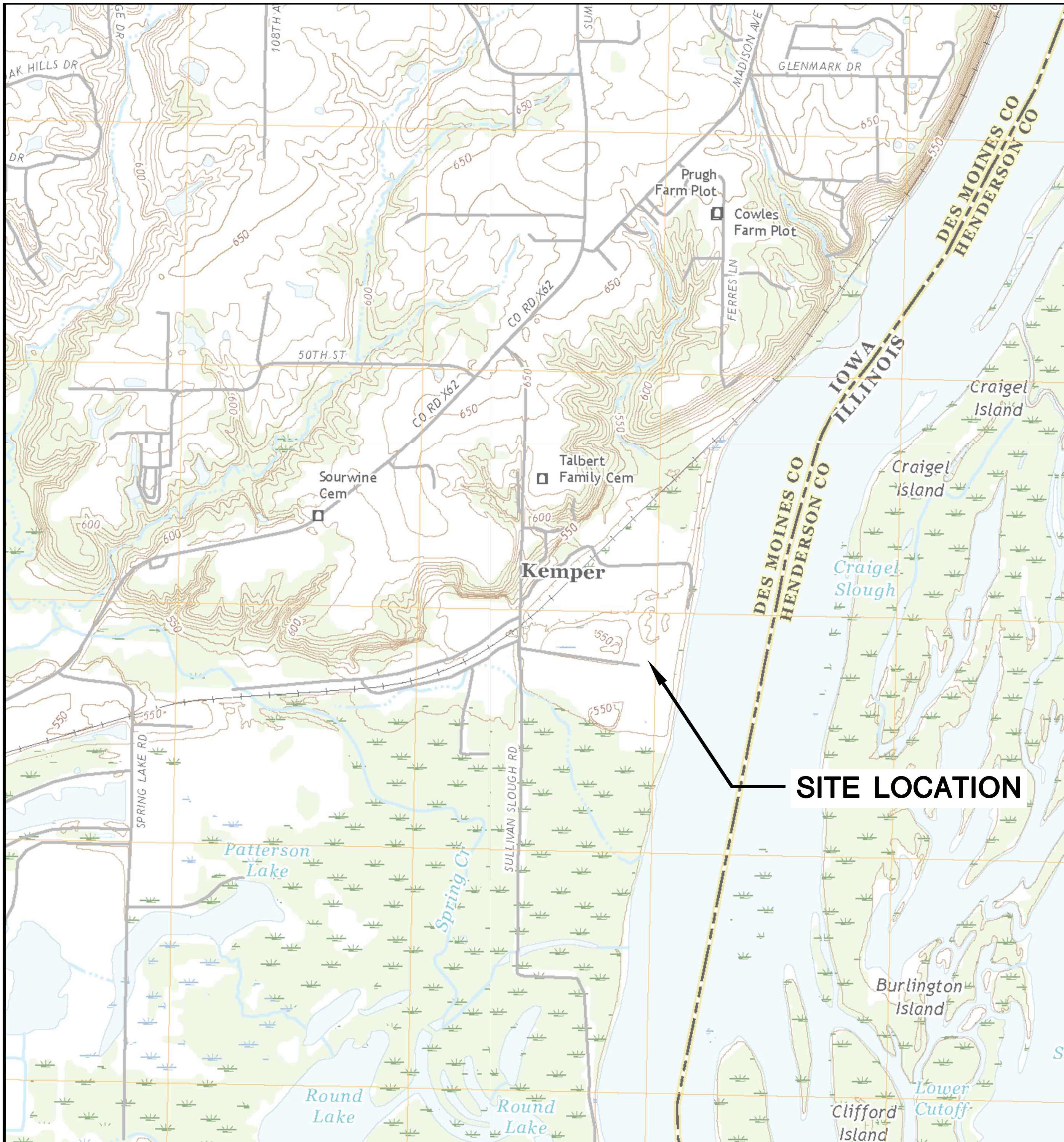
Table 3. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25220081.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill
SOURCE CONTROL TO MITIGATE FUTURE RELEASES - 40 CFR 257.97(c)(2)					
257.97(c)(2)(i) The extent to which containment practices will reduce further releases	No reduction in further releases	Cap will reduce further releases by minimizing infiltration through CCR	Same as Alternative #2 with further reduction due to consolidated/smaller closure footprint	Same as Alternative #3 with further reduction due to composite liner and 5-foot groundwater separation required by CCR Rule	Removal of CCR prevents further releases at BGS; Receiving disposal site risk similar to Alternative #3
257.97(c)(2)(ii) The extent to which treatment technologies may be used	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies
IMPLEMENTATION - 40 CFR 257.97(c)(3)					
257.97(c)(3)(i) Degree of difficulty associated with constructing the technology	Not Applicable	Low complexity construction; Potentially lowest level of dewatering effort - dewatering required for cap installation only	Low complexity construction; Moderate degree of logistical complexity; Moderate to low level of dewatering effort - dewatering required for material excavation/placement and capping	Moderate complexity construction due to composite liner and cover; High degree of logistical complexity due to excavation and on-site storage of >1M cy of CCR while new lined disposal area is constructed; Moderate to high level of dewatering effort - dewatering required for excavation of full CCR volume	Low complexity construction; High degree of logistical complexity including the excavation and off-site transport of >1M cy of CCR and permitting/development of off-site disposal facility airspace; Moderate to high level of dewatering effort - dewatering required for excavation of full CCR volume
257.97(c)(3)(ii) Expected operational reliability of the technologies	Not Applicable	High reliability based on historic use of capping as corrective measure	Same as Alternative #2	Same as Alternative #2	Success at BGS does not rely on operational reliability of technologies; Overall success relies on off-site disposal facility, which is likely same/similar to Alternative #2
IMPLEMENTATION - 40 CFR 257.97(c)(3) (continued)					
257.97(c)(3)(iii) Need to coordinate with and obtain necessary approvals and permits from other agencies	Not Applicable	Need is moderate in comparison to other alternatives State Closure Permit required; Federal/State/Local Floodplain permitting required; State and local erosion control/construction stormwater management permits required; Federal/State wetland permitting potentially required	Need is lowest in comparison to other alternatives; State Closure Permit required; State and local erosion control/construction stormwater management permits required; Federal/State/Local Floodplain permitting likely required	Need is high in comparison to other alternatives State Closure Permit required; State Landfill Permit may be required; Federal/State/Local Floodplain permitting likely required; State and local erosion control/construction stormwater management permits required; Federal/State wetland permitting likely required	Need is highest in comparison to other alternatives; State Closure Permit required; State and local erosion control/construction stormwater management permits required; Approval of off-site disposal site owner required; May require State solid waste comprehensive planning approval; Federal/State/Local Floodplain permitting likely required; Federal/State wetland permitting likely required; Local road use permits likely required
257.97(c)(3)(iv) Availability of necessary equipment and specialists	Not Applicable	Necessary equipment and specialists are highly available; Highest level of demand for cap construction material	Same as Alternative #2; Lowest level of demand for cap construction material	Same as Alternative #2; Moderate level of demand for liner and cap construction material	Availability of necessary equipment to develop necessary off-site disposal facility airspace and transport >1M cy of CCR to new disposal facility will be a limiting factor in the schedule for executing this alternative; No liner or cover material demands for on-site implementation of remedy
257.97(c)(3)(v) Available capacity and location of needed treatment, storage, and disposal services	Not Applicable	Capacity and location of treatment, storage, and disposal services is not a factor for this alternative	Capacity and location of treatment, storage, and disposal services is unlikely to be a factor for this alternative	Available temporary on-site storage capacity for >1M cy of CCR while composite liner is constructed is significant limiting factor	off-site disposal capacity, facility logistical capacity, or the time required to develop the necessary off-site disposal and logistical capacity is a significant limiting factor.
COMMUNITY ACCEPTANCE - 40 CFR 257.97(c)(4)					
257.97(c)(4) The degree to which community concerns are addressed by a potential remedy (Anticipated)	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed

Created by: LAB/SK Date: 6/20/2019
Last revision by: EJN Date: 7/31/2019
Checked by: TK Date: 9/12/2019

I:\25220081.00\Deliverables\2020 Semiannual - Selection Remedy\Tables\[Table 3 Evaluation of Assessment of Corrective Measure BGS.xlsx]BGS Evaluation Matrix

Figures



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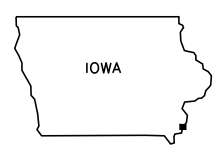
ILLINOIS / IOWA-DES MOINES CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
2018
SCALE: 1" = 2,000'



CLIENT	SITE	
ALLIANT ENERGY 4902 N. BILTMORE LANE, #1000 MADISON, WI 53718	ALLIANT ENERGY BURLINGTON GENERATING STATION BURLINGTON, IOWA	SITE LOCATION MAP

				ENGINEER	
PROJECT NO.	25220066.00	DRAWN BY:	BSS	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	FIGURE
DRAWN:	11/14/2019	CHECKED BY:	MDB		1
REVISED:	03/12/2020	APPROVED BY:	TK 03/12/2020		

I:\25220066.00\Drawings\Site Location Map.dwg, 3/12/2020 10:13:36 AM

LEGEND

- EXISTING CCR RULE MONITORING WELL
- CCR UNITS

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15–17, 2015.
2. MONITORING WELLS MW-301, MW-302, AND MW-309 THROUGH MW-311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
4. 2018 AERIAL PHOTOGRAPH SOURCES: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA FSA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY.

N

300 0 300

SCALE: 1" = 300'

PROJECT NO.	25220066.00	DRAWN BY:	BSS
DRAWN:	11/14/2019	CHECKED BY:	MDB
REVISED:	03/12/2020	APPROVED BY:	TK 03/12/2020

ENGINEER: SCS ENGINEERS, 2830 DAIRY DRIVE MADISON, WI 53718-6751, PHONE: (608) 224-2830

CLIENT: ALLIANT ENERGY, 4902 N. BILTMORE LANE, #1000, MADISON, WI 53718

SITE: ALLIANT ENERGY, BURLINGTON GENERATING STATION, BURLINGTON, IOWA

SITE PLAN AND MONITORING WELL LOCATIONS

FIGURE 2

I:\25220066.00\Drawings\Site Plan and Monitoring Well Locations.dwg, 3/12/2020 10:10:31 AM

11/25/2020 - Classification: Internal - ECRM7803923

Semiannual Progress Report Selection of Remedy – Burlington Generating Station

Burlington Generating Station
Burlington, Iowa

Prepared for:

Alliant Energy

SCS ENGINEERS

25220081.00 | September 11, 2020

2830 Dairy Drive
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1.0 INTRODUCTION AND PURPOSE

The Semiannual Progress Report for remedy selection at the Interstate Power and Light Company (IPL) Burlington Generating Station (BGS) was prepared to comply with U.S. Environmental Protection Agency (USEPA) regulations regarding the Disposal of Coal Combustion Residuals (CCR) from Electric Utilities [40 CFR 257.50-107], or the "CCR Rule" (Rule). Specifically, the selection of remedy process was initiated to fulfill the requirements of 40 CFR 257.97.

1.1 BACKGROUND

The Assessment of Corrective Measures (ACM) for the four BGS CCR units was completed on September 12, 2019. The ACM was completed in response to the detection of lithium and molybdenum at statistically significant levels above the Groundwater Protection Standard (GPS) in groundwater samples from downgradient monitoring wells. Lithium concentrations exceeded the GPS at the following downgradient monitoring wells: MW-302, MW-303, MW-307, and MW-308. Molybdenum concentrations exceeded the GPS at the following downgradient monitoring wells: MW-302, MW-307, and MW-308.

This Semiannual Progress Report summarizes data collected and remedy evaluation progress made since the ACM was completed in September 2019, and outlines planned future activities to complete the selection of remedy process. This is the second semiannual progress report, and covers the 6-month period of March 2020 through August 2020.

1.2 SITE INFORMATION AND MAPS

BGS is located along the west bank of the Mississippi River, about 5 miles south of the City of Burlington, in Des Moines County, Iowa (**Figure 1**). The address of the generating station is 4282 Sullivan Slough Road, Burlington, Iowa. In addition to the coal-fired generating station, the property also contains a coal stockpile, diesel-fueled combustion turbines, hydrated fly ash storage area, upper ash pond, lower pond, economizer ash pond, bottom ash pond, and ash seal pond.

The four CCR units at the facility (upper ash pond, economizer ash pond, bottom ash pond, and ash seal pond) are monitored with a multi-unit groundwater monitoring system and are the subject of this Semiannual Progress Report. A map showing the CCR units and all background (or upgradient) and downgradient monitoring wells with identification numbers for the CCR groundwater monitoring program is provided on **Figure 2**.

Groundwater flow at the site is generally to the south-southeast, and the groundwater flow direction and water levels fluctuate seasonally due to the proximity to the river. Depth to groundwater as measured in the site monitoring wells varies from less than 1 to 15 feet below ground surface due to topographic variations across the facility and seasonal variations in water levels.

2.0 SUMMARY OF WORK COMPLETED

Work completed to support remedy selection for the BGS CCR units is summarized in **Table 1**. Activities completed within the 6-month period covered by this semiannual report are discussed in more detail below.

Significant schedule delays occurred due to the COVID-19 pandemic. Temporary travel bans, social distancing restrictions, and pandemic response planning delayed selection of remedy activities for several months. Semiannual assessment monitoring was also delayed due to COVID-19-related restrictions.

2.1 MONITORING NETWORK CHANGES

Four deeper piezometers, located adjacent to existing monitoring wells MW-302, MW-307, MW-310, and MW-313, were scheduled to be installed in February 2020. The installations were delayed until March 2020 due to a delayed permit, and then were delayed further until June 2020 due to the COVID-19 pandemic. In addition to the delays mentioned above, the pandemic also created delays due to required revisions to time-dependent permits. All new well installations were completed in June and July 2020. The locations of all monitoring wells at BGS are shown on **Figure 2**.

2.2 GROUNDWATER MONITORING

Groundwater samples were collected in June 2020. The monitoring event was performed in June instead of April due to the COVID-19 pandemic. The June 2020 monitoring event was part of the routine semiannual assessment monitoring program. The wells sampled included the 11 wells in the original monitoring system (MW-301 through MW-311) and the two additional wells (MW-312 and MW-313) installed in May 2019. A summary of groundwater samples collected since submittal of the ACM is provided in **Table 2**.

2.3 GEOTECHNICAL INVESTIGATION

Additional geotechnical field investigation activities, including the installation of two water level monitoring points, was scheduled to begin in February 2020. The geotechnical investigation was delayed until March 2020 due to a delayed permit, and then was delayed further until June 2020 due to the COVID-19 pandemic. Preliminary evaluations of geotechnical data have also been completed, which provided insight into:

- CCR depths, elevations, and volumes
- Spatial variation and physical properties of CCR and site soils
- Water level conditions in CCR and site soils

The information obtained from the geotechnical investigation is currently being incorporated into the remedy design and selection process.

2.4 EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

A qualitative assessment of potential Corrective Measure Alternatives using the selection criteria in 40 CFR 257.97(b) and (c) was provided in the September 2019 ACM. **Table 3** summarizes the assessment completed for the ACM. No updates or changes to the assessment have been made based on additional information obtained since the issue of the ACM. Additional groundwater data collection and analysis is necessary for the evaluation of the monitored natural attenuation (MNA) option. Updates to the assessment, and development of the quantitative evaluation system discussed in the ACM, will be completed in the future based on updates to the conceptual site model, delineation of the nature and extent of impacts, and collection of additional data relevant to remedy selection.

3.0 PLANNED ACTIVITIES

Planned activities related to the remedy selection process include the following:

- Collect groundwater samples at the four new piezometers.
- Continue semiannual assessment monitoring for the existing monitoring well network and new monitoring wells.
- Evaluate MNA feasibility, including additional evaluation of groundwater flow and groundwater quality.
- Update conceptual site model based on findings of nature and extent investigation.
- Continue evaluation of remedial options.
- Conduct public meeting (40 CFR 257.96(e)).

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Tables

Table 1. Timeline for Completed Work - Selection of Remedy
Burlington Generating Station / SCS Engineers Project #25220081.00

Date	Activity
May 2019	Additional monitoring wells installed to investigate nature and extent (MW-312 and MW-313)
June 2019	Sampled new monitoring wells (MW-312 and MW-313)
September 2019	Completed the Well Documentation Report for the new wells
September 2019	Completed ACM
October 2019	Conducted semiannual assessment monitoring event, including second round of sampling for the new wells (MW-312 and MW-313)
January 2020	Completed Statistical Evaluation of October 2019 groundwater monitoring results
January 2020	Completed 2019 Annual Groundwater Monitoring and Corrective Action Report
November 2019 to spring 2020	Planning, permitting, and access arrangements for installation of four additional monitoring wells (piezometers) to investigate the vertical extent of impacts
December 2019/ January 2020	Execute source area and geotechnical field investigation

Table 1. Timeline for Completed Work - Selection of Remedy
Burlington Generating Station / SCS Engineers Project #25220081.00

Date	Activity
March 2020	Completed Semiannual Progress Report for Selection of Remedy
June 2020	Conducted semiannual* assessment monitoring event
June 2020	Completed field work for geotechnical study of impoundments
June-July 2020	Additional monitoring wells (piezometers) installed to investigate vertical groundwater flow and groundwater quality
August 2020	Initiated planning for the public ACM meeting
August 2020	Completed groundwater monitoring results letter for June 2020 sampling event

Notes:
*: Spring semiannual sampling events are typically completed in April; the spring 2020 event was delayed due to the COVID-19 pandemic

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Last revision by:	EJN	Date:	9/1/2020
Checked by:	MDB	Date:	9/1/2020

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Table 2. Groundwater Samples Summary - Events Since ACM Submittal
Burlington Generating Station / SCS Engineers Project #252220081.00

Sample Dates	Downgradient Wells											Background Wells	
	MW-301	MW-302	MW-303	MW-304	MW-305	MW-306	MW-307	MW-308	MW-309	MW-312	MW-313	MW-310	MW-311
10/10-11/2019	A	A	A	A	A	A	A	A	A	A	A	A	A
6/2-4/2020	A	A	A	A	A	A	A	A	A	A	A	A	A
Total Samples	2	2	2	2	2	2	2	2	2	2	2	2	2

Abbreviation:
A = Required by Assessment Monitoring Program

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Last revision by:	TK	Date:	8/28/2020
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I:\25220081.00\Deliverables\2020 Semiannual - Selection Remedy\September 2020 Semiannual Update\Tables\[Table 2_GW_Samples_Summary_Table_BGS.xlsx]GW Summary

Table 3. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25220081.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill
CORRECTIVE ACTION ASSESSMENT - 40 CFR 257.97(b)					
257.97(b)(1) Is remedy protective of human health and the environment?	No	Yes	Yes	Yes	Yes
257.97(b)(2) Can the remedy attain the groundwater protection standard?	Unlikely	Yes	Yes	Yes	Yes
257.97(b)(3) Can the remedy control the source(s) of releases so as to reduce or eliminate, to the maximum extent feasible, further releases of constituents in appendix IV to this part into the environment?	No	Yes	Yes	Yes	Yes
257.97(b)(4) Can the remedy remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible?	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR
257.97(b)(5) Can the remedy comply with standards for management of wastes as specified in §257.98(d)?	Not Applicable	Yes	Yes	Yes	Yes
LONG- AND SHORT-TERM EFFECTIVENESS - 40 CFR 257.97(c)(1)					
257.97(c)(1)(i) Magnitude of reduction of existing risks	No reduction of existing risk	Existing risk reduced by achieving GPS	Same as Alternative #2	Same as Alternative #2	Same as Alternative #2
257.97(c)(1)(ii) Magnitude of residual risks in terms of likelihood of further releases due to CCR remaining following implementation of a remedy	No reduction of existing risk. Residual risk is limited for all alternatives due to limited extent of impacts and lack of receptors.	Magnitude of residual risk of further releases is lower than current conditions due to final cover eliminating infiltration through CCR; Residual risk is limited for all alternatives due to limited extent of impacts and lack of receptors	Same as Alternative #2 with potential further reduction in release risk due to CCR material footprint; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts	Same as Alternative #3 with potential further reduction in release risk due to composite liner and cover; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts	Same as Alternative #3 with potential further reduction in release risk due to removal of CCR from site; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts
257.97(c)(1)(iii) The type and degree of long-term management required, including monitoring, operation, and maintenance	Not Applicable	30-year post-closure groundwater monitoring; Groundwater monitoring network maintenance and as-needed repair/replacement; Final cover maintenance (e.g., mowing and as-needed repair); Periodic final cover inspections; Additional corrective action as required based on post-closure groundwater monitoring	Same as Alternative #2	Same as Alternative #2	No on-site long-term management required; Limited on-site post-closure groundwater monitoring until GPS are achieved; Receiving disposal facility will have same/similar long-term monitoring, operation, and maintenance requirements as Alternative #2

Table 3. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25220081.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill
LONG- AND SHORT-TERM EFFECTIVENESS - 40 CFR 257.97(c)(1) (continued)					
257.97(c)(1)(iv) Short-term risks - Implementation					
Excavation	None	Limited risk to community and environment due to limited amount of excavation (<100K cy) required to establish final cover subgrades and no off-site excavation	Same as Alternative #2 with increased risk to environment due to increased excavation volumes (>100K cy, <300K cy) required for consolidation	Same as Alternative #3 with increased risk to environment due to increased excavation volumes (>1M cy) and temporary CCR storage during disposal site construction required for removal and on-site re-disposal	Same as Alternative #4 with reduced risk to environment from excavation due to limited on-site storage
Transportation	None	No risk to community or environment from off-site CCR transportation; Typical risk due to construction traffic delivering final cover materials to site	Same as Alternative #2 with reduced risk from construction traffic due to reduced final cover material requirements (smaller cap footprint)	Same as Alternative #2 with increased risk from construction traffic due to increased material import requirements (liner and cap construction required)	Highest level of community and environmental risk due to CCR volume export (>1M cy)
Re-Disposal	None	Limited risk to community and environment due to limited volume of CCR re-disposal (<100K cy)	Same as Alternative #2 with increased risk to environment due to increased excavation volumes (>100K cy, <300K cy) required for consolidation	Same as Alternative #3 with increased risk to environment due to increased excavation volumes (>1M cy) and temporary CCR storage during disposal site construction required for removal and on-site re-disposal	Same as Alternative #4 with increased risk to community and environment due to re-disposal of large CCR volume (>1M cy) at another facility; Re-disposal risks are managed by the receiving disposal facility
257.97(c)(1)(v) Time until full protection is achieved	Unknown	To be evaluated further during remedy selection. Closure and capping anticipated by end of 2022. Groundwater protection timeframe to reach GPS potentially 2 to 10 years following closure construction, achievable within 30-year post-closure monitoring period.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential for decrease in time to reach GPS due to consolidation of CCR.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential decrease in time to reach GPS due to source isolation within liner/cover system.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential decrease in time to reach GPS due to impounded CCR source removal.
257.97(c)(1)(vi) Potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, re-disposal, or containment	No change in potential exposure	Potential for exposure is low. Remaining waste is capped.	Same as Alternative #2	Same as Alternative #2	No potential for on-site exposure to remaining waste since no waste remains on site; Risk of potential exposure is transferred to receiving disposal facility and is likely similar to Alternative #2
257.97(c)(1)(vii) Long-term reliability of the engineering and institutional controls	Not Applicable	Long-term reliability of cap is good; Significant industry experience with methods/ controls; Capping is common practice/industry standard for closure in place for remediation and solid waste management	Same as Alternative #2 with potentially increased reliability due to smaller footprint and reduced maintenance	Same as Alternative #3	Success of remedy at BGS does not rely on long-term reliability of engineering or institutional controls; Overall success relies on reliability of the engineering and institutional controls at the receiving facility.
257.97(c)(1)(viii) Potential need for replacement of the remedy	Not Applicable	Limited potential for remedy replacement if maintained; Some potential for remedy enhancement due to residual groundwater impacts following source control	Same as Alternative #2 with reduced potential need for remedy enhancement with consolidated/smaller closure area footprint	Same as Alternative #2 with further reduction in potential need for remedy enhancement composite with liner	No on-site potential for remedy replacement; Limited potential for remedy enhancement due to residual groundwater impacts following source control

Table 3. Preliminary Evaluation of Corrective Measure Alternatives
Burlington Generating Station / SCS Engineers Project #25220081.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-site Landfill
SOURCE CONTROL TO MITIGATE FUTURE RELEASES - 40 CFR 257.97(c)(2)					
257.97(c)(2)(i) The extent to which containment practices will reduce further releases	No reduction in further releases	Cap will reduce further releases by minimizing infiltration through CCR	Same as Alternative #2 with further reduction due to consolidated/smaller closure footprint	Same as Alternative #3 with further reduction due to composite liner and 5-foot groundwater separation required by CCR Rule	Removal of CCR prevents further releases at BGS; Receiving disposal site risk similar to Alternative #3
257.97(c)(2)(ii) The extent to which treatment technologies may be used	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies
IMPLEMENTATION - 40 CFR 257.97(c)(3)					
257.97(c)(3)(i) Degree of difficulty associated with constructing the technology	Not Applicable	Low complexity construction; Potentially lowest level of dewatering effort - dewatering required for cap installation only	Low complexity construction; Moderate degree of logistical complexity; Moderate to low level of dewatering effort - dewatering required for material excavation/placement and capping	Moderate complexity construction due to composite liner and cover; High degree of logistical complexity due to excavation and on-site storage of >1M cy of CCR while new lined disposal area is constructed; Moderate to high level of dewatering effort - dewatering required for excavation of full CCR volume	Low complexity construction; High degree of logistical complexity including the excavation and off-site transport of >1M cy of CCR and permitting/development of off-site disposal facility airspace; Moderate to high level of dewatering effort - dewatering required for excavation of full CCR volume
257.97(c)(3)(ii) Expected operational reliability of the technologies	Not Applicable	High reliability based on historic use of capping as corrective measure	Same as Alternative #2	Same as Alternative #2	Success at BGS does not rely on operational reliability of technologies; Overall success relies on off-site disposal facility, which is likely same/similar to Alternative #2
IMPLEMENTATION - 40 CFR 257.97(c)(3) (continued)					
257.97(c)(3)(iii) Need to coordinate with and obtain necessary approvals and permits from other agencies	Not Applicable	Need is moderate in comparison to other alternatives State Closure Permit required; Federal/State/Local Floodplain permitting required; State and local erosion control/construction stormwater management permits required; Federal/State wetland permitting potentially required	Need is lowest in comparison to other alternatives; State Closure Permit required; State and local erosion control/construction stormwater management permits required; Federal/State/Local Floodplain permitting likely required	Need is high in comparison to other alternatives State Closure Permit required; State Landfill Permit may be required; Federal/State/Local Floodplain permitting likely required; State and local erosion control/construction stormwater management permits required; Federal/State wetland permitting likely required	Need is highest in comparison to other alternatives; State Closure Permit required; State and local erosion control/construction stormwater management permits required; Approval of off-site disposal site owner required; May require State solid waste comprehensive planning approval; Federal/State/Local Floodplain permitting likely required; Federal/State wetland permitting likely required; Local road use permits likely required
257.97(c)(3)(iv) Availability of necessary equipment and specialists	Not Applicable	Necessary equipment and specialists are highly available; Highest level of demand for cap construction material	Same as Alternative #2; Lowest level of demand for cap construction material	Same as Alternative #2; Moderate level of demand for liner and cap construction material	Availability of necessary equipment to develop necessary off-site disposal facility airspace and transport >1M cy of CCR to new disposal facility will be a limiting factor in the schedule for executing this alternative; No liner or cover material demands for on-site implementation of remedy
257.97(c)(3)(v) Available capacity and location of needed treatment, storage, and disposal services	Not Applicable	Capacity and location of treatment, storage, and disposal services is not a factor for this alternative	Capacity and location of treatment, storage, and disposal services is unlikely to be a factor for this alternative	Available temporary on-site storage capacity for >1M cy of CCR while composite liner is constructed is significant limiting factor	off-site disposal capacity, facility logistical capacity, or the time required to develop the necessary off-site disposal and logistical capacity is a significant limiting factor.
COMMUNITY ACCEPTANCE - 40 CFR 257.97(c)(4)					
257.97(c)(4) The degree to which community concerns are addressed by a potential remedy (Anticipated)	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed

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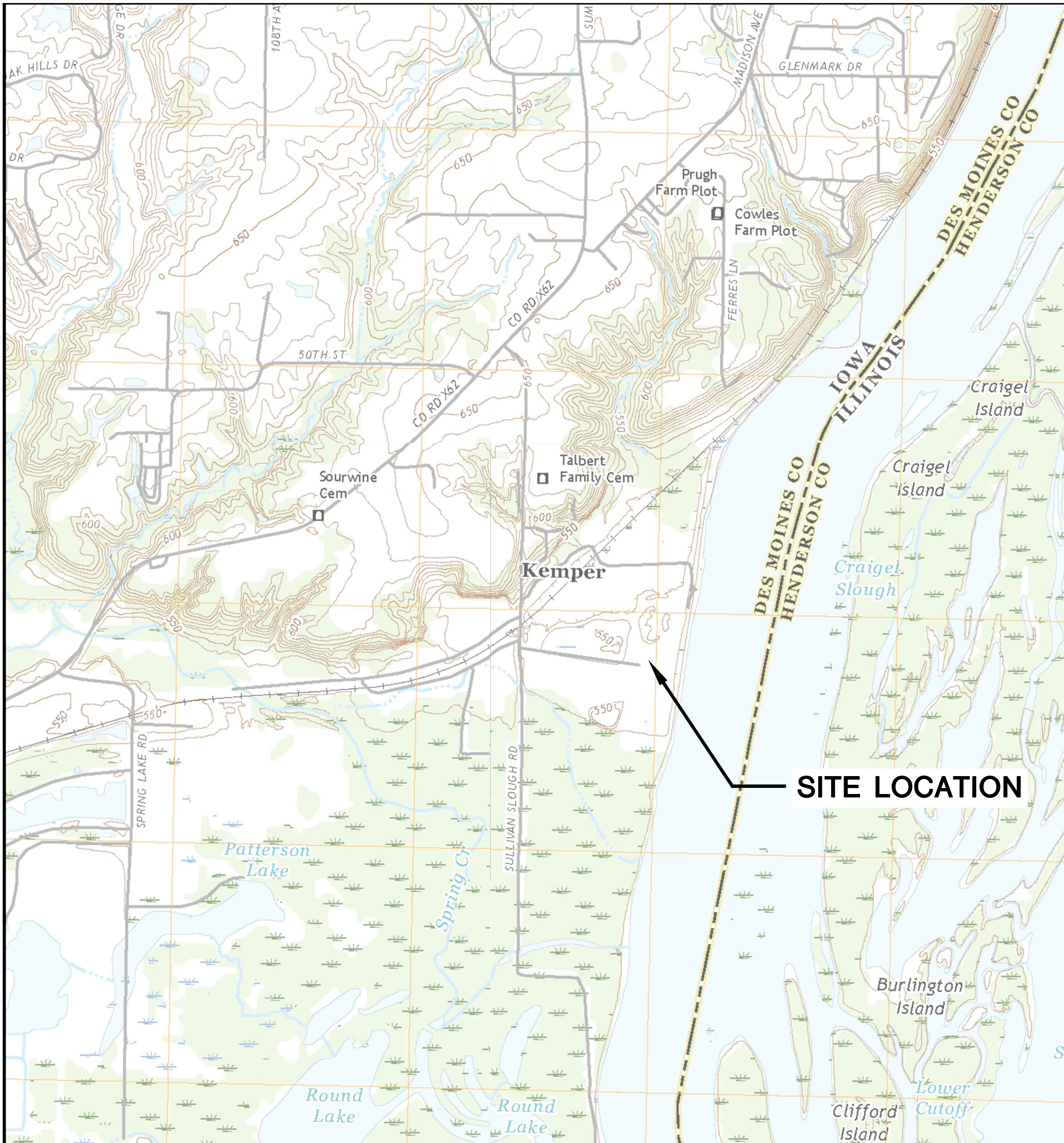
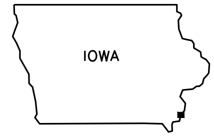
Figures



N

LOMAX QUADRANGLE
ILLINOIS / IOWA-DES MOINES CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
2018
SCALE: 1" = 2,000'



CLIENT	SITE	
ALLIANT ENERGY 4902 N. BILTMORE LANE, #1000 MADISON, WI 53718	ALLIANT ENERGY BURLINGTON GENERATING STATION BURLINGTON, IOWA	SITE LOCATION MAP

				ENGINEER	FIGURE
PROJECT NO.	25220066.00	DRAWN BY:	BSS	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	1
DRAWN:	11/14/2019	CHECKED BY:	MDB		
REVISED:	03/12/2020	APPROVED BY:	TK 03/12/2020		

I:\25220066.00\Drawings\Site Location Map.dwg, 3/12/2020 10:13:36 AM

LEGEND

- EXISTING CCR RULE MONITORING WELL
- EXISTING CCR RULE PIEZOMETER
- CCR UNITS

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW-301, MW-302, AND MW-309 THROUGH MW-311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
4. 2018 AERIAL PHOTOGRAPH SOURCES: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA FSA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY.

PROJECT NO.	25220066.00	DRAWN BY:	BSS/KRG
DRAWN:	11/14/2019	CHECKED BY:	MDB
REVISED:	08/28/2020	APPROVED BY:	EJN 9/11/2020

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4902 N. BILTMORE LANE, #1000
MADISON, WI 53718

SITE: ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

SITE PLAN AND MONITORING WELL LOCATIONS

FIGURE 2

Appendix E

Initial Structural Stability Assessment (August 2016)

Structural Stability Assessment

Ash Seal Pond	
Stable Foundations and Abutments	The embankments consist of sand and compacted clay fill soils. As demonstrated by the Safety Factor Assessment (see **Appendix F**), the foundations and abutments are adequate to support the impoundment infrastructure and pond contents.
Slope Protection	The embankment slopes are vegetated. The well-established and managed vegetation will minimize erosion on the upstream and downstream slopes.
Embankment Density	Based on the results of 2011 borings, the in-place soil embankment densities were identified for the Safety Factor Assessment (**Appendix F**). The analysis results in **Appendix F** indicate that the embankment densities ae sufficient to withstand the loading conditions analyzed.
Vegetation Management	The embankments have dense grassy vegetation. The facility provides periodic maintenance for the vegetation.
Spillway Management	The pond is a zero discharge impoundment. A pump is used to remove excess water if storm water accumulates faster than infiltration occurs at the base. The CCR unit has a significant hazard potential classification requiring evaluation of a 1,000-year rainfall event. Analysis of this event indicates that the precipitation will be contained within the limits of the CCR unit without overtopping the embankments.
Hydraulic Structures	There is no active hydraulic structure associated with this CCR unit.
Sudden Drawdown	A 100-year Mississippi River flood elevation will crest above the CCR unit embankment. In the event of drawdown, drainage would occur through the sand base of the CCR unit. Sand zones within the embankment were sealed in 2007 by constructing a soil bentonite wall through the embankment to prevent seepage through the sand zones. There are no factors that would result in slumping of the embankment toe as a flood recedes.

Main Ash Pond	
Stable Foundations and Abutments	The CCR unit embankments were investigated with borings and testing in 2011. The embankment foundation is suitable to support the embankment and CCR unit contents. This conclusion is supported by the analysis results in the Safety Factor Assessment (**Appendix F**).
Slope Protection	The embankment slopes are vegetated. The well-established and managed vegetation will minimize erosion on the upstream and downstream slopes.
Embankment Density	The embankment clay soils have adequate density to support the loads from the CCR unit contents.
Vegetation Management	The CCR unit embankments have been managed to remove woody deep rooting vegetation and maintain the grassy vegetation.
Spillway Management	The CCR unit discharges through two culvert pipes under the plant access road. Facility personnel inspect the culverts weekly for signs of malfunction such as blockage or deformation. The CCR unit has a significant hazard potential classification requiring evaluation of a 1,000 year rainfall event. Analysis of this event indicates precipitation will drain through the culverts without overtopping the embankments.
Hydraulic Structures	The CCR unit discharge is through two culvert pipes. In June 2016, the pipes were inspected using remote camera video. The inspection found there was minimal deterioration, deformation, distortion, sedimentation, and debris with no observed bedding deficiencies.
Sudden Drawdown	The CCR unit south embankment is subject to flood water from the Mississippi River that may rise to the embankment crest. The embankment clay soils are not subject to rapid drawdown impacts to the embankment slopes.

Economizer Pond	
Stable Foundations and Abutments	The clay soils are a stable foundation where present. Loose CCR materials within the north embankment are potentially unstable during earthquake loading conditions. The analysis in **Appendix F** indicates the CCR north embankment materials would likely liquefy during the design earthquake. If liquefaction occurred, the CCR foundation materials would allow the north embankment to slump and spread into the Upper Ash Pond. At the end of the earthquake, the residual strength of the embankment foundation would be adequate to prevent further movement. Due to the configuration of the Economizer Pond, the release of water across the slope instead of through the designed discharge is unlikely.
Slope Protection	The embankment slopes are vegetated. The well-established and managed vegetation will minimize erosion on the upstream and downstream slopes.
Embankment Density	The clay embankments have adequate density and strength to contain the CCR contents. The CCR embankment has a potential to liquefy during the design earthquake as described above. With the exception of the CCR liquefaction potential, the density and strength of embankments are acceptable as shown by the Safety Factor Assessment (**Appendix F**).
Vegetation Management	The CCR unit embankments have been managed to remove woody deep rooting vegetation and maintain the grassy vegetation.
Spillway Management	Process water and storm water are pumped to the top of the Economizer Pond embankment. The water moves through an open channel and a discharge pipe. During storms, the primary discharge pipe may flow full while a second discharge pipe passes the remaining flow. In an extreme flow event, water could overflow the west embankment that would act as an emergency spillway. The CCR unit has a significant hazard potential classification requiring an evaluation of a 1,000-year rainfall event. Analysis of this event indicates water would overflow down the emergency spillway likely resulting in some embankment erosion requiring subsequent repair. Facility personnel perform weekly inspection of the discharge pipes for malfunction such as blockage or deformation.
Hydraulic Structures	The discharge structures consist of three pipes. In June 2016, the pipes were inspected using remote camera video. The inspection indicated there was minimal deterioration, deformation, distortion, sedimentation, and debris with no observed bedding deficiencies.
Sudden Drawdown	The embankments are not subject to flood conditions. The outer embankment slopes will not experience rapid drawdown conditions.

Upper Ash Pond	
Stable Foundations and Abutments	The CCR unit embankments consist of clay and sand soils. The embankment foundation is suitable to support the embankment and CCR unit contents. This conclusion is supported by the analysis results in the Safety Factor Assessment (**Appendix F**).
Slope Protection	The north embankment slopes are protected with rip rap to allow overtopping of the embankment by flood water. The rip rap protects the embankment from erosion due to overtopping and wave action.
Embankment Density	The embankment clay soils have adequate density to support the loads from the CCR unit contents as shown in **Appendices E** and **F**.
Vegetation Management	The CCR unit west embankment has been managed to maintain the grassy vegetation.
Spillway Management	The CCR unit discharges through a flume, catch basin, and pipe to the Lower Pond. Facility personnel inspect these structures weekly for malfunctions such as blockage or deformation. The CCR unit has a significant hazard potential classification requiring evaluation of a 1,000-year rainfall event. Analysis of this event indicates the CCR unit will drain through the hydraulic structures without overtopping the embankment.
Hydraulic Structures	The CCR unit discharge pipes include a main pipe and an emergency overflow pipe. In June 2016, the pipes were inspected using remote camera video. The inspection found there was minimal deterioration, deformation, distortion, sedimentation, and debris with no observed bedding deficiencies.
Sudden Drawdown	The CCR unit embankment and its foundation consist of clay. The embankment clay soils are not subject to rapid drawdown impacts to the embankment slopes.

ALLIANT ENERGY
Interstate Power and Light Company
Burlington Generating Station

CCR SURFACE IMPOUNDMENT

STRUCTURAL STABILITY ASSESSMENT

Report Issued: August 25, 2016
Revision 0

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EXECUTIVE SUMMARY

This Structural Stability Assessment (Report) is prepared in accordance with the requirements of the United States Environmental Protection Agency (USEPA) published Final Rule for Hazardous and Solid Waste Management System – Disposal of Coal Combustion Residual (CCR) from Electric Utilities (40 CFR Parts 257 and 261, also known as the CCR Rule) published on April 17, 2015 and effective October 19, 2015.

This Report assesses the structural stability of each CCR unit at Burlington Generating Station in Burlington, Iowa in accordance with §257.73(b) and §257.73(d) of the CCR Rule. For purposes of this Report, "CCR unit" refers to an existing CCR surface impoundment.

Primarily, this Report documents whether the design, construction, operation, and maintenance of the CCR unit is consistent with recognized and generally accepted good engineering practices for the maximum volume of CCR and CCR wastewater which can be impounded within each CCR unit.

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1 Introduction

The owner or operator of the Coal Combustion Residual (CCR) unit must conduct an initial and periodic structural stability assessments and document whether the design, construction, operation, and maintenance of the CCR unit is consistent with recognized and generally accepted good engineering practices for the maximum volume of CCR and CCR wastewater which can be impounded therein. This Report has been prepared in accordance with the requirements of §257.73(b) and §257.73(d) of the CCR Rule.

1.1 CCR Rule Applicability

The CCR Rule requires a periodic structural stability assessment by a qualified professional engineer (PE) for existing CCR surface impoundments with a height of 5 feet or more and a storage volume of 20 acre-feet or more; or the existing CCR surface impoundment has a height of 20 feet or more (§257.73(b)).

1.2 Structural Stability Assessment Applicability

The Burlington Generating Station (BGS) in Burlington, Iowa (Figure 1) has four existing CCR surface impoundments that meet the requirements of §257.73(b)(1) or §257.73(b)(2) of the CCR Rule, which are identified as follows:

- BGS Ash Seal Pond
- BGS Main Ash Pond
- BGS Economizer Pond
- BGS Upper Ash Pond

2 FACILITY DESCRIPTION

The following sub-section provides a summary description of the facility and existing CCR surface impoundments located at BGS.

BGS is located southeast of the City of Burlington, Iowa on the western shore of the Mississippi River in Des Moines County, at 4282 Sullivan Slough Road, Burlington, Iowa (Figure 1). BGS is a fossil-fueled electric generating station consisting of one steam electric generating unit and four combustion turbine units. Sub-bituminous coal is the primary fuel for producing steam, and natural gas is used for the combustion turbines. The burning of coal in the steam electric unit produces CCR. The CCR at BGS is categorized into three types, bottom ash, economizer ash, and precipitator fly ash.

Date of Initial Facility Operations:	1968
NPDES Permit Number:	IA29-00-1-01
Facility Title V Operating Permit:	98-TV-023R1-M004
Latitude / Longitude:	40°44'29"N 91°07'04"W
Site Coordinates:	Section 29, Township 69 North, Range 02 West
Unit Nameplate Ratings:	Unit 1: 212 MW

2.1 BGS Ash Seal Pond

The BGS Ash Seal Pond is located south of the generating plant and east of the BGS Main Ash Pond. The CCR, in 1968, was originally managed by discharging into the BGS Ash Seal Pond for settling. Presently, the BGS Ash Seal Pond only receives storm water runoff from the surrounding area associated with the fly ash storage silo. The BGS Ash Seal Pond also may receive facility process water, such as ash seal water, but only if there is an issue with the ash seal water pumps. At the time of the initial annual inspection on October 26, 2015 this CCR surface impoundment did not contain standing water.

The surface area of the BGS Ash Seal Pond is approximately 5.7 acres and has an embankment height of approximately 12 feet from the crest to the toe of the downstream slope. The embankment crest is at elevation 534 the same as the adjacent plant site grade and equivalent to the 100 year flood water elevation of the Mississippi River. The interior storage depth of the BGS Ash Seal Pond is approximately 12 feet. If water were present, the total volume of impounded CCR and water within the BGS Ash Seal Pond would be approximately 97,000 cubic yards, which would include general fill that has been added in the northeast corner of the impoundment. The original outfall for the impoundment is sealed to prevent discharge to the Mississippi River and the impoundment normally contains no water. Rainfall that accumulates exfiltrates through the bottom of the impoundment. A manually operated pump is available to lift storm water to the adjacent BGS Main Ash Pond, if necessary.

2.2 BGS Main Ash Pond

The BGS Main Ash Pond is located southwest of the generating plant and west of the BGS Ash Seal Pond. The CCR, prior to being sluiced to the BGS Main Ash Pond, was originally managed in the BGS Ash Seal Pond in 1968. In 1971, BGS managed CCR in the BGS Upper Ash Pond. In 1980, the BGS Main Ash Pond became the primary receiver of CCR, with the BGS Upper Ash Pond becoming a downstream receiver.

Presently, the BGS Main Ash Pond receives bottom ash that is sluiced from the generating plant to the northeast corner of the BGS Main Ash Pond. The sluiced bottom ash discharges into the northeast corner where the majority of the bottom ash settles out. The bottom ash that settles out is recovered for beneficial reuse. Hydrated fly ash is also stored within the BGS Main Ash Pond area prior to being sold as aggregate material for beneficial reuse. Fly ash from the on-site storage silo is no longer added to the embankment.

The water that is used to sluice the bottom ash into the BGS Main Ash Pond is routed towards the west end of the BGS Main Ash Pond. The water is discharged in batch quantities as bottom ash accumulates in the boiler and averages 1 cubic foot per second (cfs) on a daily basis. The water flows to the west along the north side of a road constructed out of bottom ash through the center of the BGS Main Ash Pond, Figure 2. The water flows along the north side of the road until it reaches the west end where it transitions into a ponded area in the northwest corner of the BGS Main Ash Pond. The water in the northwest corner of the BGS Main Ash Pond flows through two 15 inch diameter corrugated metal culverts with identical invert elevation under the generating plant entrance road. The water discharges into a small channel in the southwest corner of the BGS Upper Ash Pond located north of the generating plant entrance road.

The surface area of the BGS Main Ash Pond is approximately 18.7 acres and has an embankment height of approximately 12 feet from the crest to the toe of the downstream slope. The embankment crest is at elevation 534 the same as the plant site grade and equivalent to the 100 year flood water elevation in the Mississippi River. The interior storage depth of the BGS Main Ash Pond is approximately 8 feet. The total volume of impounded CCR and water within the BGS Main Ash Pond at normal water operation elevation is approximately 240,000 cubic yards. Additional volume of impounded CCR, located in the eastern half of the BGS Main Ash Pond above the crest elevation of the embankment, includes the bottom ash storage area and C-stone embankment (hydrated fly ash). In 2008, the quantity of the additional CCR above the crest elevation of the embankment is approximately 104,000 cubic yards.

2.3 BGS Economizer Pond

The BGS Economizer Pond is located west of the generating plant and north of the BGS Main Ash Pond. In 1986, BGS constructed the BGS Economizer Pond in the southern and eastern portion of the original footprint of the BGS Upper Ash Pond. The impoundment has resulted from economizer ash that has been deposited since 1986, which created the economizer embankment which is higher than the embankments of the BGS Upper Ash Pond at approximately elevation 548.

Presently, the BGS Economizer Pond receives economizer ash. The economizer ash is sluiced from the generating plant to the east end of the BGS Economizer Pond via a 10-

inch diameter polyvinyl chloride pipe at a flow rate of 1.5 cfs (including approximately 10% plant process water). The economizer ash settles out through the water column of the 0.4 acre BGS Economizer Pond while the water flows to the west. The water discharges from the BGS Economizer Pond through an 18-inch diameter high-density polyethylene pipe into a storm water and process water treatment channel located along the south side of the economizer embankment.

The storm water and process water treatment channel receives runoff from 8 acres surrounding the generating plant. The collected storm water drains into a pump vault located at the toe of the downstream slope of the east embankment of the BGS Economizer Pond. Plant process water flows through an oil/water separator and receives influent flows from the plant floor drains and water treatment process water. After the oil/water separator, the process water discharges into the pump vault. The storm water and process water is then pumped from the vault up to the storm water treatment channel. The storm water treatment channel flows to the west along the south side of the economizer embankment until it discharges through an 18-inch diameter high-density polyethylene pipe located in the southwest corner of the economizer embankment. The water from the storm water treatment channel discharges into a small channel in the southwest corner of the BGS Upper Ash Pond located north of the generating plant entrance road.

The total surface area of the BGS Economizer Pond and economizer embankment is approximately 11 acres and has an embankment height of approximately 13 feet from the crest to the toe of slope on the CCR in the BGS Upper Ash Pond. The interior storage depth of the top of the economizer embankment to the bottom of the original footprint of the BGS Upper Ash Pond is approximately 27 feet. Thus, the total volume of impounded CCR and water within the BGS Economizer Pond including CCR already in place when the impoundment was established is approximately 480,000 cubic yards.

2.4 BGS Upper Ash Pond

The BGS Upper Ash Pond is located northwest of the generating plant and north of the BGS Main Ash Pond. In 1971, BGS began managing CCR in the BGS Upper Ash Pond. In 1980, the BGS Main Ash Pond became the primary receiver of CCR and the BGS Upper Ash Pond became a downstream receiver of the BGS Main Ash Pond.

Presently, the BGS Upper Ash Pond receives influent flows from the BGS Main Ash Pond, BGS Economizer Pond, and storm water and process water flow from the generating plant. The influent flows all discharge into a small channel located in the southwest corner of the BGS Upper Ash Pond. The water in the channel routed along the south side of the gravel dike of the BGS Upper Ash Pond until it discharges into the southwest corner of the BGS Upper Ash Pond water body.

The water flows through the BGS Upper Ash Pond water body to the northeast towards a 24-inch wide precast concrete Parshall flume that discharges into a concrete catch basin. The water in the catch basin flows through a 15-inch diameter polyvinyl chloride pipe and discharges into the BGS Lower Pond. Instrumentation associated with the BGS Upper Ash Pond includes a flow meter that monitors the discharges. The discharge from the concrete catch basin enters the Lower Pond. The Lower Pond contains the facility's National Pollution Discharge Elimination System (NPDES) Outfall 001. The water flows through the NPDES Outfall 001 hydraulic structure, which consists of cast in place weir box.

The total surface area of the BGS Upper Ash Pond is approximately 13.3 acres and has an embankment height of approximately 10 feet from the crest to the toe of the downstream slope. The elevation of the embankments is 531 feet, 3 feet lower than the 100 year flood elevation of the Mississippi River. The embankment is armored with cobble size stone on the crest and both outer and inner embankment slopes to prevent erosion of the embankment during overtopping from extreme flood stage of the Mississippi River. The interior storage depth of the BGS Upper Ash Pond is approximately 7 feet. The volume of impounded CCR and water within the BGS Upper Ash Pond at normal operation water elevation is approximately 150,000 cubic yards.

3 STRUCTURAL STABILITY ASSESSMENT- §257.73(d)

This Report documents the design, construction, operation, and maintenance of the BGS CCR units are consistent with recognized and generally accepted good engineering practices for maximum volume of CCR and CCR wastewater which can be impounded.

3.1 BGS Ash Seal Pond

The BGS Ash Seal Pond receives surface water runoff from an approximate area of 2 acres south of the main generating station complex including the dry fly ash handling silo and truck loading area. The northeast corner of the impoundment (approximately 25% of its original footprint) is filled to plant grade of 534 feet. Rainfall that directly enters the impoundment or enters as surface water is stored in the impoundment without discharge. Because the subsoil below the base of the impoundment is sandy due to its location on the natural river levee deposits, the accumulated rain water exfiltrates into the subsurface.

Soil borings and testing taken for plant construction activities and for determination of embankment properties as illustrated on Figure 3 and presented in Appendices A, B, C and D. The results indicate the embankments are constructed of clay compacted over naturally occurring sand and clay. Strength properties of the soils were measured by Standard Split Spoon Penetration (ASTM D 1586) or Cone Penetrometer testing (ASTM D 5778).

3.1.1 CCR Unit Foundation and Abutments - §257.73(d)(1)(i)

The partial excavation and construction of embankments for the BGS Ash Seal Pond occurred during the original construction of the plant. The south and west sides of the impoundment were constructed embankments and the east and north sides were incised below plant design grade. The embankments consist of a mixture of on-site soils from excavation in the sandy levee deposits and off-site clay imported from higher land west of the site. Deep borings taken for construction in the plant area show that the subsurface soils below elevation 510 feet is medium dense sand. Medium dense sand is a strong subbase for the impoundment embankments. Soil between elevation 510 and the bottom of the impoundment at elevation 520 is generally loose sand and silty sand that remained in place and is partially below the normal water elevation of the Mississippi River elevation 518. The foundations and abutments for the BGS Ash Seal Pond are adequate to support the impoundment infrastructure and contents as demonstrated in the Safety Factor Assessment Report.

3.1.2 Slope Protection - §257.73(d)(1)(ii)

The BGS Ash Seal Pond is incised on the east, north and west sides. The south side faces the condenser discharge channel for the generating station where non-contact cooling water is released in a channel back to the Mississippi River. The crest of the south embankment is approximately 12 feet wide and the downstream slope of the exposed embankment is a 2:1 vegetated slope. Well established and managed vegetation will minimize erosion on both the upstream and downstream slopes. Additionally, storm water runoff is limited to the crest and downstream slope of the embankment, which limits the erosive force. Therefore the impoundment configuration protects against surface erosion.

Wave erosion potential is reduced because the downstream slope is protected within the condenser discharge channel. Wave action is unlikely to produce erosive forces that would affect the BGS Ash Seal Pond embankment.

Sudden drawdown is addressed in Section 3.1.7.

3.1.3 CCR Embankment Density- §257.73(d)(1)(iii)

In 2011, soil borings and penetration tests were taken in the south embankment of the BGS Ash Seal Pond. The results indicate the embankment is low plasticity silty clay (CL) with some layers of loose to medium dense sand. The in place embankment densities identified within the Safety Factor Assessment Report are sufficient to withstand the range of loading conditions that were analyzed.

3.1.4 Vegetation Management - §257.73(d)(1)(iv)

Historically vegetation management has been conducted on a periodic basis. At the time of the initial Annual Inspection in October 2015, the bottom half of the downstream slope could not be properly inspected due to the presence of dense/tall grassy vegetation. During the Spring of 2016, the facility reduced the height of the vegetation to facilitate effective inspections. The facility plans to either continue maintaining the vegetation in a manner that facilitates effective inspection or to armor the slope.

3.1.5 Spillway Management - §257.73(d)(1)(v)

The BGS Ash Seal Pond is currently a zero discharge impoundment. The former spillway, which consisted of a 18-inch PVC pipe, is permanently sealed with hydraulic cement. If rainwater accumulates faster than it exfiltrates, a pump is used to send water to the BGS Main Ash Pond adjacent to the west side of the BGS Ash Seal Pond, Figure 2.

This impoundment currently has a hazard potential classification of "Significant," which in turn requires an evaluation of the impacts of a 1,000 year rainfall event. The Inflow Flood Control Plan, which is a separate document developed to comply with §257.82, shows that the precipitation from this event will be contained within the limits of the impoundment without overtopping the embankments. The freeboard at peak flow will be approximately 7-inches.

3.1.6 Hydraulic Structures - §257.73(d)(1)(vi)

No active hydraulic structures are associated with this BGS Ash Seal Pond. The abandoned discharge pipe is completely filled with concrete and the June 20, 2016 pipe inspection showed no signs of deterioration, deformation, or distortion.

3.1.7 Sudden Drawdown - §257.73(d)(1)(vii)

A Mississippi River flood of 100 year elevation will rise to the crest elevation of the south embankment. Rise of the flood on the Mississippi River is often rapid, but drawdown is slower. In the event of drawdown, drainage would occur through the sandy base of the dam, but not through the dam embankment that is mainly clay. Some sand intervals in the embankment shown on the borings in Appendix B were sealed in 2007 by the construction of a soil bentonite wall through the embankment to prevent seepage through the sand seams.

There are no factors that would result in slumping of the embankment toe as the flood recedes and the embankment has been exposed to multiple cycles of drawdown since construction that have not impacted the downstream slope.

3.2 BGS Main Ash Pond

The BGS Main Ash Pond was constructed in 1972 to replace the BGS Upper Ash Pond as the main receiver of CCR at the BGS. The impoundment was constructed on soft clay deposits in the backwater areas between the plant site and high ground to the west. The embankments are constructed of imported clay from a borrow site just west of the BGS. Borings and penetration tests taken in 2011 and presented in Appendices B, C, and D indicate that the embankment is low plasticity silty clay (CL). The underlying foundation of the embankment is a soft clay deposited in backwater flooding of the Mississippi. Beneath the soft clay is a medium dense sand layer common to the Mississippi River valley.

3.2.1 CCR Unit Foundation and Abutments - §257.73(d)(1)(i)

The foundation soils for the embankments are soft clay that is surcharged by the weight of the embankment soil. Below the clay is a medium dense sand layer that is typical of the Mississippi River valley. The embankment foundation is adequate to support the embankment and the contents of the CCR impoundment. The test results in Appendix D indicate that the foundation soils are low plasticity clay that is not subject to liquefaction during earthquake events. The foundation soils are adequate to support the embankments and the CCR as indicated in the Safety Factor Assessment Report.

3.2.2 Slope Protection - §257.73(d)(1)(ii)

The impoundment is incised on the north and east sides. The toe of the west embankment drains south and into the wetland area. The south embankment faces a large wetland classified by the U.S. Fish and Wildlife Service National Wetlands Inventory as a

"Freshwater Forested/Shrub Wetland" with Classification Codes: PF01A (135 acres) and PF01C (559 acres). The wetland area is nearly flat, where drainage flows east and ultimately ends up in the discharge channel for the facility where non-contact cooling water is released in a channel back to the Mississippi River. The crest of the embankments is approximately 12 feet wide and the downstream slope of the embankment varies between a 3:1 and 2:1 vegetated slope. Well established and managed vegetation will minimize surface erosion on both the upstream and downstream slopes. Additionally, storm water runoff is limited to the crest and downstream slope of the embankment, which limits the erosive force. Therefore the impoundment configuration protects against surface erosion.

Erosion due to wave action will have minimal impacts to the embankments as the 25 year flood event or greater of the Mississippi River will cause backwater to approach the embankments.

Sudden drawdown is addressed in Section 3.2.7.

3.2.3 CCR Embankment Density- §257.73(d)(1)(iii)

The embankment soil is silty clay typical of the surrounding uplands and as shown by the data in Appendix C and has adequate density to support the pressures from the CCR contents of the impoundments.

3.2.4 Vegetation Management - §257.73(d)(1)(iv)

Historically vegetation management has been conducted on a periodic basis. At the time of the initial Annual Inspection in October 2015, the upstream and downstream slopes of could not be properly inspected due to the presence of dense/tall brush and woody vegetation along the entire slope. Since the Annual Inspection, the facility has removed woody vegetation, including mature trees, from the embankment and has managed the remaining grassy vegetation to facilitate effective inspections. The facility plans to continue managing the grassy vegetation on the embankments at a height that facilitates effective inspections.

3.2.5 Spillway Management - §257.73(d)(1)(v)

The BGS Main Ash Pond is equipped with two 15 inch diameter corrugated steel culverts to drain process water and storm water under the plant access road at the northwest corner of the impoundment, Figure 2. The culverts are constructed of non-erodible material and designed to carry sustained flows.

The culverts are checked for malfunction (e.g., blockages, deformations) during the weekly inspections by the facility personnel.

This impoundment currently has a hazard potential classification of "Significant," which in turn requires an evaluation of the impacts of a 1,000 year rainfall event. The Inflow Flood Control Plan, which is a separate document developed to comply with §257.82, shows that the precipitation from this event will drain through the culverts without overtopping the embankments of the impoundment. The freeboard at peak flow will be approximately 8 inches.

3.2.6 Hydraulic Structures - §257.73(d)(1)(vi)

The discharge structures from the BGS Main Ash Pond are comprised of two 15-inch diameter corrugated metal culverts with identical invert elevation under the generating plant entrance road. On June 20, 2016 the pipes were inspected using remote camera video inspection. The inspection showed that there was minimal deterioration, deformation, distortion, sedimentation, debris, and no bedding deficiencies were observed.

3.2.7 Sudden Drawdown - §257.73(d)(1)(vii)

The south embankment of the BGS Main Ash Pond is subject to the rise and fall of flood water from the Mississippi River as high as the crest of the embankment. These water elevations have occurred during major floods of the Mississippi River at least four times since construction of the impoundment[1] and many smaller river floods have created sudden drawdown conditions on the embankment.

[1] Records of the United States Army Corps of Engineers for Pool 19 of Mississippi River.

The embankments and the subsurface are both soft to medium stiff low plasticity clay and there no rapid drawdown impacts to the embankment outer slopes.

3.3 BGS Economizer Pond

The BGS Economizer Pond is constructed on top of the southern part of the BGS Upper Ash Pond. It was constructed by raising the clay embankment of the BGS Upper Ash Pond on the south and east sides of the impoundment and by building a clay embankment on top of the CCR in the BGS Upper Ash Pond on the west side and the western end of the north side of the impoundment. On the eastern end of the north side of the impoundment, the embankment on top of the CCR in the BGS Upper Ash Pond is constructed entirely of CCR.

The BGS Economizer Pond has received both economizer ash and fly ash, but is presently used only for settling and recovery of economizer ash. The impoundment is actually a piled CCR embankment with surface water only on the southern edge of the impoundment where there is a clay embankment. The northern slope of the embankment has a toe that sits on CCR in the BGS Upper Ash Pond and was regraded in 2011 to have a flat slope of 5 horizontal to 1 vertical to limit the effects of poor embankment foundation soils.

Soil borings, penetration tests and laboratory tests on the impoundment embankments or slopes are shown in Appendices B, C and D. The boring locations are shown on Figure 3. The results indicate clay embankments and native clays that are classified as soft to medium stiff low plasticity clay (CL) and CCR with friction angles from 30 to 34 degrees. The CCR is very loose to medium dense cohesionless soil. The layer density varies in the unsaturated parts of the embankment (likely from cementation). The bottom ten feet of the CCR is saturated by the water in the BGS Upper Ash Pond and is very loose to loose.

3.3.1 CCR Unit Foundation and Abutments - §257.73(d)(1)(i)

The saturated very loose CCR in the north embankment of the BGS Upper Ash Pond is potentially an unstable foundation under earthquake loading conditions. The native clay soils are a stable foundation where present. The analysis completed in the Safety Factor Assessment Report, §257.73(b), indicates that the foundation soils would likely liquefy during the design earthquake with a 2500 year return period.

In the event of liquefaction, the foundation soils would allow the embankment to slump and spread north into the BGS Upper Ash Pond during the strong motion part of the earthquake that would last approximately 30 seconds. At the end of the shaking, the residual strength of the foundation would be adequate to arrest further movement. Since the only water in the impoundment is far south of the slope, the release of water across the slope to the north instead of through the designed discharge at the west end of the impoundment is unlikely.

3.3.2 Slope Protection - §257.73(d)(1)(ii)

The economizer embankment is approximately 13 feet above the surrounding grade. The side slopes are vegetated and vary from 2:1 to 5:1. Well established and managed vegetation will minimize erosion on both the upstream and downstream slopes. Additionally, the storm water runoff is limited to the crest and downstream slope of the embankment, which limits the erosive force. Therefore the impoundment configuration protects against surface erosion.

The economizer embankment is located where the embankments will likely not be inundated by water which eliminates the potential for wave erosion.

Sudden drawdown is addressed in Section 3.3.7.

3.3.3 CCR Embankment Density- §257.73(d)(1)(iii)

The constructed clay embankments are soft to medium stiff low plasticity clay and have adequate strength to contain the CCR contents. The dry parts of the embankment constructed of CCR is loose to medium dense and cemented in certain layers. It will not move unless the foundation layers below the water table displace as described in 3.3.1. The strength of the embankments are acceptable as shown in the Safety Factor Assessment Report.

3.3.4 Vegetation Management - §257.73(d)(1)(iv)

Historically vegetation management has been conducted on a periodic basis. At the time of the initial Annual Inspection in October 2015, the downstream slope of the west embankment of the BGS Economizer Pond could not be properly inspected due to the presence of dense/tall grassy vegetation along the bottom third (1/3) of the slope. The rest of the embankments were found to have adequately managed vegetation. Since the Annual Inspection, the facility has maintained the vegetation to facilitate effective inspections. The facility intends to continue maintaining the vegetation in a manner that facilitates effective inspections.

3.3.5 Spillway Management - §257.73(d)(1)(v)

The impoundment receives approximately 1.5 cfs of process water flow from the BGS and storm water from the BGS plant site. Both sources of water are pumped to the top of the embankment. The pumped storm water is limited by the capacity of the pumps and if the water is not lifted to the embankment it will accumulate on the plant site and under emergency conditions will surface drain to the east end of the BGS Upper Ash Pond.

The process water that is pumped to the top of the embankment passes through a small settling impoundment to remove the economizer ash and then by an open channel to an 18 -inch diameter HDPE discharge pipe at the west end of the embankment. Storm water is discharged directly to the open channel and passes through the same discharge pipe. During storms where both storm water pumps are running, the primary discharge pipe flows full and an emergency 12-inch diameter steel discharge pipe will pass a part of the remaining flow. Therefore, in extreme events where two pumps run for an extended time, the water could overflow the embankment at the west end where the embankment height is one foot lower, which would act as an emergency spillway. The HDPE and steel pipes are constructed of non-erodible materials and designed to carry sustained flows.

This impoundment currently has a hazard potential classification of “Significant,” which in turn requires an evaluation of the impacts of a 1,000 year rainfall event of 10.3 inches. The Inflow Flood Control Plan, which is a separate document developed to comply with

§257.82, shows that the 1,000 year event would cause both the primary and secondary spillway pipes to flow at capacity and that that water would overflow down the embankment emergency spillway. The duration of the emergency spillway flow would be approximately 1 hour at a discharge total of 0.33 acre-foot.

During the duration of the overflow, it is likely that the non-erosive velocities would be exceeded. Maintenance of the spillway would likely be required after the event to restore erosion of the spillway. Flow over the emergency spillway that erodes or transports CCR would likely be contained within the BGS Upper Ash Pond.

The pipes are checked for malfunction (e.g., blockages, deformations) during the weekly inspections by the facility personnel.

3.3.6 Hydraulic Structures - §257.73(d)(1)(vi)

The discharge structures from the BGS Economizer Pond are comprised of two 18-inch HDPE pipes and one 12-inch steel pipe. On June 20, 2016 the pipes were inspected using remote camera video inspection. The inspection showed that there was minimal deterioration, deformation, distortion, sedimentation, debris, and no bedding deficiencies were observed.

3.3.7 Sudden Drawdown - §257.73(d)(1)(vii)

The BGS Economizer Pond is not subject to flood rise and fall on the toe of the embankment. The only variation is the change in ground water elevation in the embankment as the BGS Upper Ash Pond rises from its normal operation elevation of 528 to 530.5 feet during flood flow conditions. Therefore the outer embankments slopes are not subject to rapid drawdown conditions.

3.4 BGS Upper Ash Pond

The BGS Upper Ash Pond was constructed of imported clay embankment placed over natural clay and sand deposited by the Mississippi River. Test borings locations on the BGS Upper Ash Pond are shown on Figure 3. The boring results and laboratory test results are presented in Appendices B, C, and D.

The embankment soil is a low plasticity clay (CL) of medium stiff consistency. The native clay under the embankment is soft and the sand below the clay is medium dense.

Water enters the impoundment in the southwest corner and exits at an overflow flume at the northeast corner. The flume discharges into a manhole with a 15 inch diameter PVC discharge pipe which carries the water to the Lower Pond. The impoundment also contains a 14-inch diameter steel secondary overflow pipe that has a manual valve at the discharge end of the pipe.

3.4.1 CCR Unit Foundation and Abutments - §257.73(d)(1)(i)

The foundation soils are clays and sands deposited by the Mississippi River. The clay and sand strength is adequate to support the embankment, as discussed in the Safety Factor Assessment.

3.4.2 Slope Protection - §257.73(d)(1)(ii)

Both the upstream and downstream slopes of the embankment and the crest are covered with gravel and rip-rap to allow overtopping of the embankment by flood waters of the Mississippi River. The crest elevation of 531 feet on the embankment creates overtopping whenever the Mississippi River flood elevation exceeds the 25 year return event. Additionally, storm water runoff is limited to the crest and downstream slope of the embankment, which limits the erosive force. Therefore the impoundment configuration protects against surface erosion.

The BGS Upper Pond rip-rap protects against erosion from wave action.

Sudden drawdown is addressed in Section 3.4.7.

3.4.3 CCR Embankment Density- §257.73(d)(1)(iii)

The clay embankment is medium stiff clay and is stronger than the foundation soils. The strength of the embankments are acceptable as shown in the Safety Factor Assessment Report.

3.4.4 Vegetation Management - §257.73(d)(1)(iv)

Vegetation management is not required on the north embankment of the impoundment as the upstream and downstream slopes of the embankment are covered with gravel and rip-rap. At the time of the initial Annual Inspection in October 2015, the upstream and downstream slope of the south end of the west embankment of the BGS Upper Ash Pond could not be properly inspected due to the presence of dense grassy vegetation. Since the Annual Inspection, the facility has managed the vegetation to facilitate effective inspections, and the facility intends to continue managing the vegetation to facilitate effective inspections.

3.4.5 Spillway Management - §257.73(d)(1)(v)

The BGS Upper Pond discharge structure is equipped with a 24-inch wide precast concrete Parshall flume that discharges into a concrete catch basin. The water in the catch basin flows through a 15-inch diameter polyvinyl chloride pipe and discharges into the BGS Lower Pond. The pipes are constructed of non-erodible materials and designed to carry sustained flows.

The pipes are checked for malfunction (e.g., blockages, deformations) during the weekly inspections by the facility personnel.

This impoundment currently has a hazard potential classification of "Significant," which in turn requires an evaluation of the impacts of a 1,000 year rainfall event. The Inflow Flood Control Plan, which is a separate document developed to comply with §257.82, shows that the precipitation from this event will drain through the Parshall flume without overtopping the embankments of the impoundment. The freeboard at peak flow will be approximately 9 inches. The Inflow Flood Control Plan indicates a peak flow of 9.2 cfs with a storage of 30 acre feet during the flood.

3.4.6 Hydraulic Structures - §257.73(d)(1)(vi)

The discharge structure from the BGS Upper Ash Pond are comprised of one 15-inch PVC pipes and one 15-inch emergency overflow pipe. On June 20, 2016 the pipes were inspected using remote camera video inspection. The inspection showed that there was minimal deterioration, deformation, distortion, sedimentation, debris, and no bedding deficiencies were observed.

3.4.7 Sudden Drawdown - §257.73(d)(1)(vii)

The embankment and its foundation is constructed of clay and is not subject to rapid drawdown impacts on the outside toe. The embankment is flooded at the toe on numerous occasions each year without detrimental effect.

4 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

To meet the requirements of 40 CFR 257.73(d)(3), I Mark W. Loerop hereby certify that I am a licensed professional engineer in the State of Iowa; and that, to the best of my knowledge, all information contained in this document is correct and the document was prepared in compliance with all applicable requirements in 40 CFR 257.73(b) and 40 CFR 257.73(d).

LICENSED PROFESSIONAL ENGINEER
MARK W. LOEROP
22197
IOWA

By: [signature]

Name: MARK LOEROP

Date: 8-25-2016

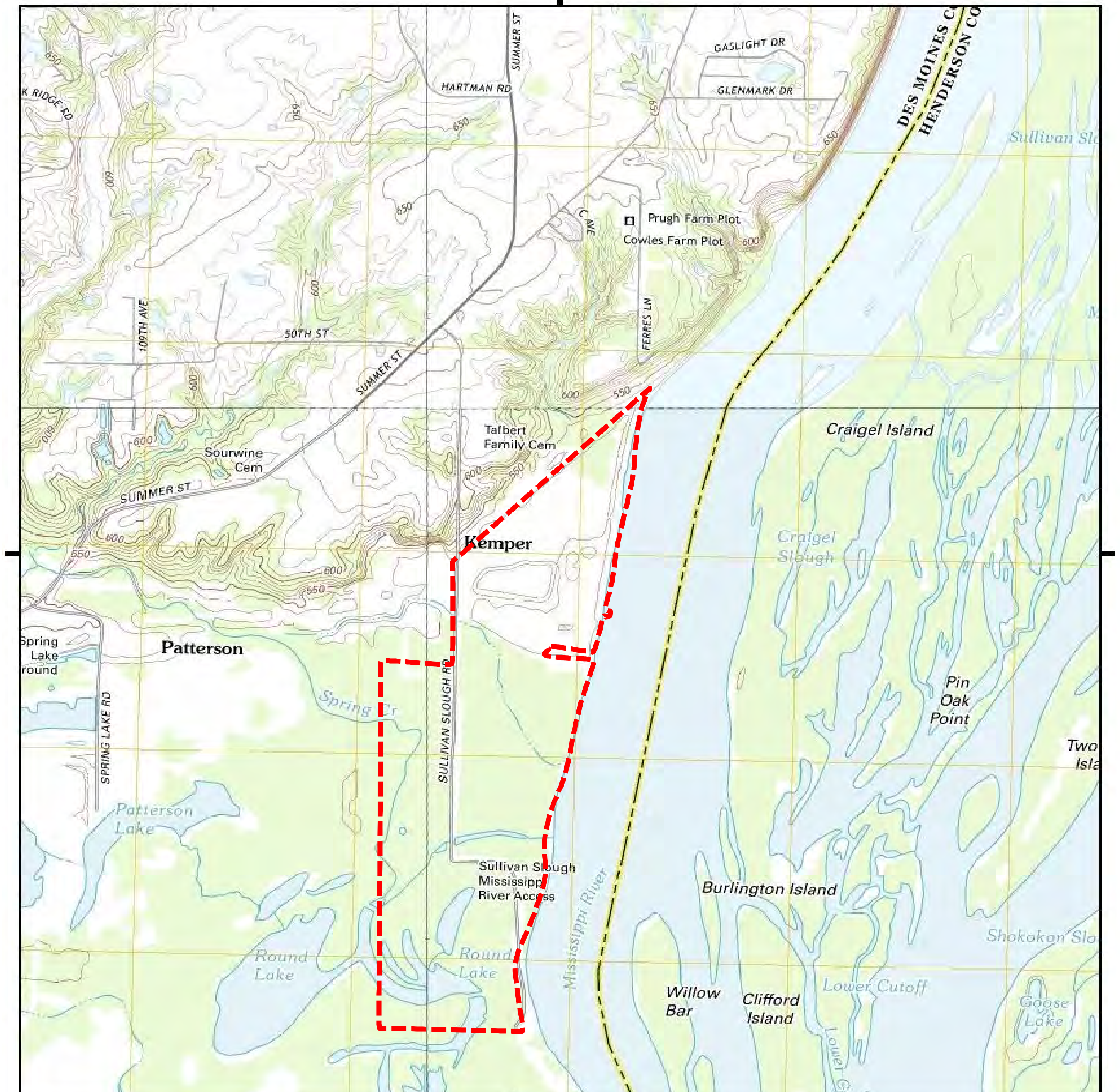
FIGURES

Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

Structural Stability Assessment

Historical Topo Map

2012, 2013



This report includes information from the following map sheet(s).

Miles 0.25 0.5 1 1.5

NW N NE W E SW S SE

TP, Lomax, 2012, 7.5-minute

NE, Burlington, 2013, 7.5-minute

SW, Dallas City, 2012, 7.5-minute

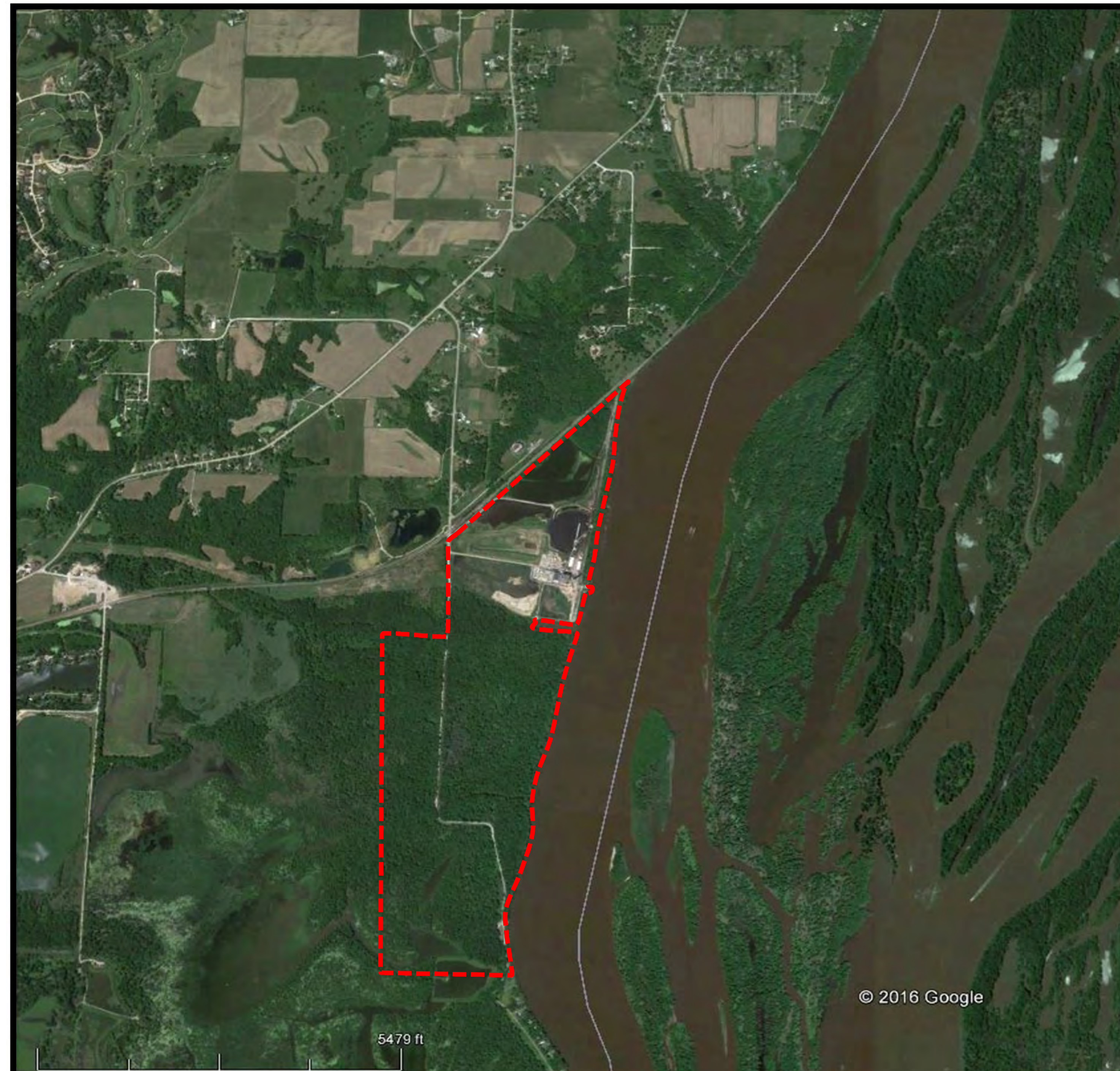
NW, West Burlington, 2013, 7.5-minute

SITE NAME: Burlington Generating Station
ADDRESS: 4282 Sullivan Slough Road
Burlington, IA 52601
CLIENT: Environmental Site Assessors

N

4555570 - 3 page 4

Historical Aerial Photo 6/12/2014



Approximate Property Boundary

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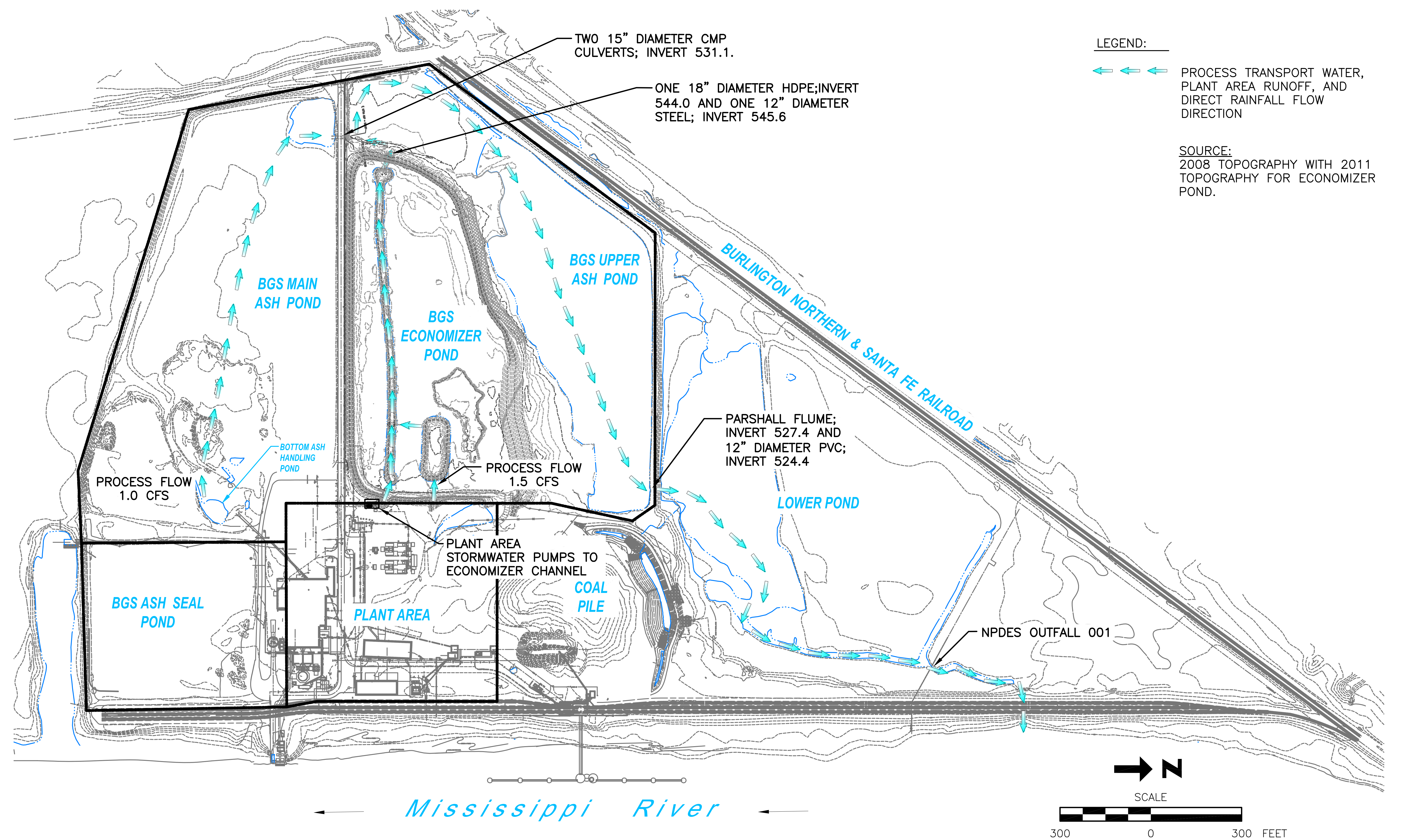
Site Location	Drawing
Burlington Generating Station Intersate Power and Light Company	Figure 1
	Date 5/25/2016



NOTICE	REV	DATE	BY	DESCRIPTION
THIS DRAWING IS THE PROPERTY OF HARD HAT SERVICES AND IS NOT TO BE REPRODUCED, CHANGED, OR COPIED IN ANY FORM OR MANNER WITHOUT PRIOR WRITTEN PERMISSION. ALL RIGHTS RESERVED.	5			
	4			
	3			
	2			
	1			

SCALE: AS SHOWN | DATE: 5–13–16

DRAWN BY: JFD | CHECKED BY: TJH | APPROVED BY: MWL

HARD HAT SERVICES ™
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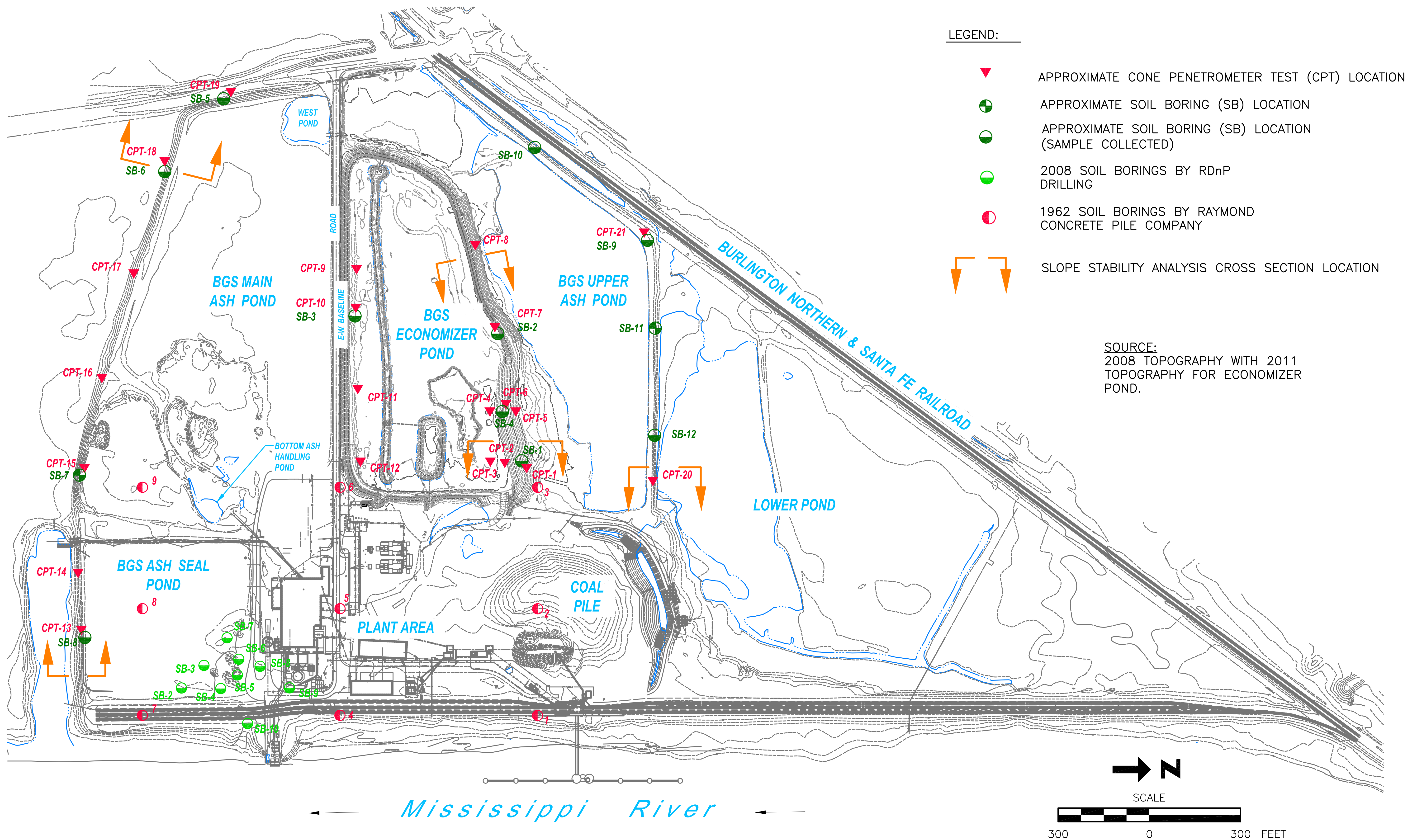
CLIENT / LOCATION
ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

DRAWING DESCRIPTION
Structural Stability Analysis
SITE PLAN

JOB 154.018.012.001
SHT. FIGURE 1
DWG. 154.018.012.001–D1



SCALE: AS SHOWN	DATE: 5-13-16	CLIENT / LOCATION	DRAWING DESCRIPTION
DRAWN BY: JFD	CHECKED BY: TJH / APPROVED BY: MWL	ALLIANT ENERGY BURLINGTON GENERATING STATION BURLINGTON, IOWA	SOIL BORINGS, CPT, AND SLOPE STABILITY CROSS SECTION LOCATIONS

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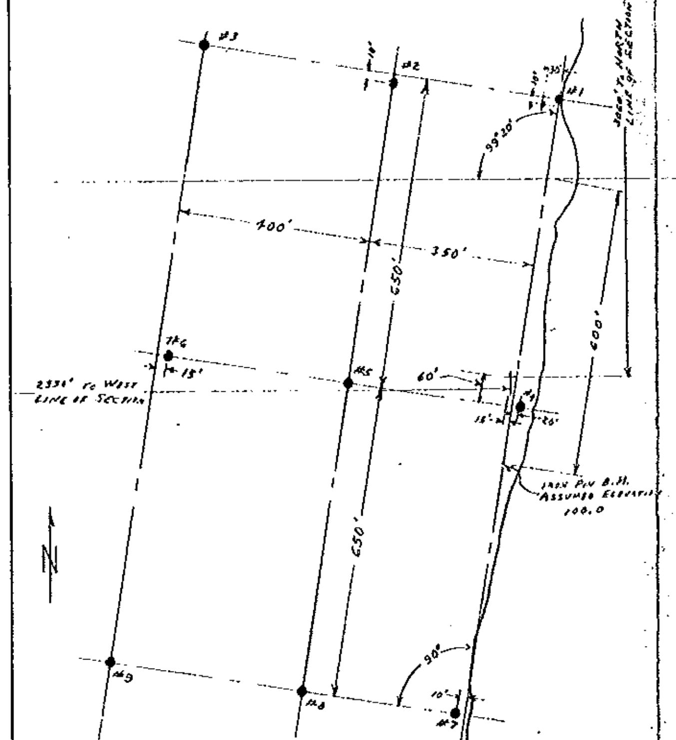
REV	DATE	BY	DESCRIPTION
5			
4			
3			
2			
1			

JOB 154.018.012.001
SHT. FIGURE 2
DWG. 154.018.012.001-D2

APPENDIX A – Deep Soil Borings

Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

Structural Stability Assessment



No. 1		
Ground Surface — Elev. 99.8		0'0"
Brown and Grey Silt and Clay	11	3'0"
Brown Silty Fine Sand	10, 2	8'0"
Brown & Grey Silty Clay	4	11'0"
Grey Fine and Medium Sand	8, ‡ 4	22'0"
Grey Fine and Medium to Coarse Sand Trace Small Gravel	‡ 4, ‡ 3	33'0"
Same More Dense	13, ‡ 11, ‡ 16	48'0"
Grey Fine to Medium Sand	‡ 3, ‡ 3	53'6"
Brown Fine Medium to Coarse Sand	‡ 6	63'0"
Brown Fine Medium and Coarse Sand Trace Small Gravel	‡ 11	68'0"
Brown Dense Fine to Medium Sand	‡ 35	72'6"
Brown Coarse Sand Trace Fine to Medium Sand	‡ 11, ‡ 17	82'6"
Brown Compact F/ Medium to Coarse Sd. Tr. Small Gravel	34	84'6"
Compact Silt with Small Gravel	52	88'0"
Same More Dense	100, 100/10	96'10"

Used 86' of 2-1/2" Casing
Water Level 4' on Completion
1/25/62

No. 2		
Ground Surface — Elev. 97.7		0'0"
Grey Silty Clay	3, 2, 2, 2	12'0"
Grey Fine Medium to Coarse Sand	8	17'0"
Grey Fine Sand	‡ 6	23'6"
Grey Fine Medium to Coarse Sand Trace Small Gravel	‡ 3, ‡ 6, ‡ 9, ‡ 9	42'6"
Grey Fine to Medium Sand	‡ 12	48'0"
Grey Fine Sand	‡ 16	55'0"
Brown Fine Medium to Coarse Sand Trace Small Gravel	‡ 9, ‡ 9, ‡ 8	70'0"
Same More Dense	15	74'4"
Grey Compact Silt with Small Seams of Fine Sand	100/11, 73, 102	86'0"

Used 81' of 2-1/2" Casing
Water Level 2' on Completion
1/27/62

No. 3		
Ground Surface — Elev. 98.4		0'0"
Brown Silty Clay	3	3'0"
Grey Silty Clay	4	7'0"
Grey and Brown Sty. Fine Sand	4	8'0"
Brown Silty Fine Sand	‡ 11	13'0"
Grey and Brown Fine Medium to Coarse Sand Trace Small Gravel	6	17'0"
Brown Fine Medium to Coarse Sand Trace Small Gravel	9, ‡ 6	21'0"
Brown Silty Fine Sand	‡ 11	33'0"
Brown Fine Medium to Coarse Sand	‡ 6, ‡ 6	43'6"
Brown Fine to Medium Sand	‡ 3	46'0"
Brown Fine Medium to Coarse Sand Trace Small Gravel	‡ 7, ‡ 15, ‡ 20, ‡ 41	68'0"
Brown and Grey Compact Silt, Fine Medium to Coarse Sand, Trace Small Gravel	110	73'0"
Grey Compact Silt Fine to Medium Sand	100, 100/8	80'2"

Used 78' of 2-1/2" Casing
Water Level 3' on Completion
1/31/62

No. 4		
Ground Surface — Elev. 99.1		0'0"
Silt		2'0"
Fine Grey Sand Some Silt	2, 2, 5	Sandy Silt 9'6"
Coarse Br. Sand Some Shells to Medium Gravel	22	13'0"
Fine to Coarse Grey Sand	5, 15, 16, 13, 16, 14, 13, 15, 17, 18, 13	61'0"
Fine Grey Sand	23	74'0"
Fine to Coarse Gr. Sand Sm. to Med. Gvl. Tr. of Clay	21/6	75'6"

Used 73' of 2-1/2" Casing
Water Level 7' on Completion
1/10/62

No. 5		
Ground Surface — Elev. 98.7		0'0"
Grey Silty Clay	5, 6, 1, 3	11'6"
Grey Fine Medium to Coarse Sand Trace Small Gravel	‡ 10, ‡ 3, ‡ 6, ‡ 5, ‡ 14, ‡ 13, ‡ 6	47'6"
Grey Silty Fine Sand	‡ 7	53'0"
Grey Fine Medium to Coarse Sand Trace Small Gravel	‡ 5, ‡ 11, 13, 14	75'5"
Grey Compact Silt and Fine Sand	40	77'6"
Grey Compact Silt, Fine to Medium Sand, Trace Clay, Trace Small Gravel	97	83'0"
Grey Compact Fine to Medium Sand Trace Clay	53	90'0"
Grey Compact Fine to Medium Sand	100/11, 100/10, 100/8	103'2"

Used 93'6" of 2-1/2" Casing
Water Level 3' Below Ground Surface
1/15/62

No. 6		
Ground Surface — Elev. 97.4		0'0"
Grey Silty Clay	2, 2, 2, 2	10'6"
Grey Fine Medium to Coarse Sand Trace Small Gravel	5, 5, 11, 10, 2, 5, 6, 6	52'0"
Grey Fine Medium to Coarse Sand	‡ 10	58'0"
Grey Fine Medium to Coarse Sand Trace Small Gravel	‡ 8, 5	69'0"
Grey Fine Medium to Coarse Sand Trace Sm. Gravel Trace Limestone Fragments	50	74'6"
Compact Silt with Some Sand	70	78'0"
Grey Compact Sty. Fine Sand Trace Medium Sand	120/10	80'11"

Used 75' of 2-1/2" Casing
Water Level 3' Below Ground Surface
1/22/62

No. 7		
Ground Surface — Elev. 100.4		0'0"
Brown Silty Trace Clay	5, 6	6'0"
Grey Silty Clay	4	9'0"
Brown Silty Fine and Medium Sand	17	13'0"
Brown Silty Fine Sand	‡ 11	17'0"
Grey Fine Medium and Coarse Sand	‡ 9, ‡ 15, ‡ 3	33'0"
Grey Silty Fine Sand Trace Mica	8	37'0"
Grey Silty Fine Medium & Coarse Sand	‡ 11	43'6"
Grey and Brown Fine Medium Coarse Sand Trace Small Gravel	‡ 11, ‡ 8, ‡ 5, ‡ 4, ‡ 15	63'6"
Grey Compact Silt Fine Medium and Coarse Sand Trace Small Gravel, Trace Clay	31	75'6"
Same More Dense	120/[illegible]	80'0"
See Note A	91	82'0"

Used 78' of 2-1/2" Casing
Used 82' of 70' Casing
Water Level 1'6" Below Ground Surface
Note A — Grey Compact Fine to Medium Sand Trace Coarse Sand & Silt
2/1/62

No. 8		
Ground Surface — Elev. 98.1		0'0"
Brown Silty Clay	3	3'0"
Grey & Brown Silty Clay	2, 2	7'0"
Brown Fine Medium and Coarse Sand	11	12'0"
Brown & Grey Fine to Coarse Medium Sand Trace Silt	3	17'6"
Grey Fine Medium to Coarse Sand Trace Silt Trace Small Gravel	8, ‡ 6, ‡ 3, ‡ 6	37'0"
Grey Fine to Medium Sand, Trace Coarse Sand	‡ 4	43'0"
Grey Fine Medium to Coarse Sand Trace Small Gravel	‡ 10, ‡ 6, ‡ 9	64'0"
Grey Compact Fine Sand and Silt Tr. Medium Gravel	100/9	68'0"
Grey Compact Fine Sand	65	70'6"
Grey Compact Fine Sand and Silt Trace Medium to Coarse Sand	100/9	75'0"

Used 75' of 70' Casing
Used 70' of 2-1/2" Casing
Water Level 3'6" Below Ground Surface
2/2/62

No. 9		
Ground Surface — Elev. 98.1		0'0"
Brown Silty Clay	2, 2	7'0"
Br. Sty. F/Sand	2	8'6"
Same More Dense	8, 9	17'6"
Grey Silty Fine to Medium Sand Trace Mica	‡ 2, ‡ 3	29'0"
Grey Silty Fine Sand, Trace Medium Sd. & Dec. Wood	‡ 5	33'0"
Grey Fine Medium to Coarse Sand Tr. Sm. Gravel	‡ 5	38'0"
Grey Fine and Medium Sand	‡ 9	42'0"
Grey Fine to Medium Sand	‡ 6	48'0"
Grey Fine Medium to Coarse Sand Tr. Sm. Gravel	‡ 3	53'0"
Same More Dense	‡ 11, ‡ 24, ‡ 26	67'0"
Grey Compact Medium to Coarse Sand Trace Small Gravel	‡ 100/6, 100/12	73'10"

Used 73'10" of 70' Casing
Used 70' of 2-1/2" Casing
Water Level 2'6" Below Ground Surface
2/5/62

Figures in Right Hand Column Shown as Fractions — Numerator = No. of Blows; Denominator = Penetration in Inches
‡ Indicates Wash Sample Recovered

Classifications are made by visual inspection. Figures in right hand column indicate number of blows required to drive 2" O.D. sampling pipe one foot, using 140-lb. weight falling 30 inches.

References:
See D-461 for Boring Locations.
Test Boring Report - February 13, 1962, by Raymond Concrete Pile Company, Soil Division, Job No. C8-948-KC Sheets 1 through 4

IOWA SOUTHERN UTILITIES CO.
CENTERVILLE, IOWA
Proposed Burlington Plant Site
Test Boring Reports
Scale 1" = 8' Vertical — Date 3-15-62
Sketch [illegible] DWN — TRCD L.L. CHKD
D-484
Approved

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Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-2**
LOGGED BY LES
PAGE No. 1 of 2

PROJECT NAME: Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION: Burlington, Iowa
SURFACE ELEVATION: 534.13
DRILLER: RDnP Drilling - Kris Norwick
DATE: START 12/11/2008 FINISH 12/12/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	2	3	4	4	14.0		0.75			CL	Black and brown mottled SILTY CLAY, little fine to medium sand, medium plasticity, medium stiff, wet
											4'3"	529.88		
5	SS-2	4.0	6.0	1	6	5	3	17.0						Grey SILT, trace fine sand, medium dense, moist
	SS-3	6.0	8.0	1	8	15	7	17.5						medium dense
	SS-4	8.0	10.0	1	6	50/5		18.0					ML	very dense
10														
	SS-5	13.0	15.0	1	1	1	1	13.0	49	0.75	13'5"	520.71		
15														Dark brown and black mottled CLAY, trace silt, high plasticity, medium stiff, wet
	SS-6	18.0	20.0	2	2	3	3	15.0	48	0.25 0.50			CH	soft (LL=52, PI=27)
20														
	SS-7	23.0	25.0	4	5	7	12	20.0			23'6"	510.63		Brown fine to medium SAND, medium dense, wet
25														
	SS-8	28.0	30.0	3	12	17	18	9.0						brownish-grey
30														
	SS-9	33.0	35.0	8	10	11	12	11.5					SP	
35														
	SS-10	38.0	40.0	7	7	10	12	10.0						some coarse sand and wood pieces
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES ™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-2**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.13
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/11/2008 FINISH 12/12/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Brownish-grey fine to medium sand, some coarse sand, medium dense, wet (cont.)
	SS-11	43.0	45.0	3	6	12	14	15.5					SP	2" of black silt at 44'1"
45														
											46'6"	487.63		Brownish-grey fine to coarse SAND, medium dense, wet
	SS-12	48.0	50.0	6	7	8	12	16.0						
50														
	SS-13	53.0	55.0	10	11	12	19	21.0					SW	
55														
	SS-14	58.0	60.0	15	22	32	42	24.0						medium to coarse sand, trace fine sand and fine gravel, very dense
60											60'	474.13		EOB 60' - Sand was causing hole to collapse and would have needed to be cased to 60' to continue.
65														
70														
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BORING LOG

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

PROJECT No. 154.002.008.001
BORING No. BH-B-1 **(BH-3)**
LOGGED BY LES
PAGE No. 1 of 2

PROJECT NAME Alliant Energy - Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
DRILLER RDnP Drilling - Chris DATE: START 7/15/2008 FINISH 7/21/2008

DEPTH	SAMPLE No.	INTERVAL FROM	INTERVAL TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	USCS SOIL TYPE	SOIL DESCRIPTION
	SS-1	0.0	2.0	5	10	10	12	12	23				Brown and black silty clay FILL, medium dense, dry
	SS-2	2.0	4.0	10	11	11	15	9.5		2.0			Coarse sand and fine gravel FILL, trace grey fines, medium dense, dry
5	SS-3	4.0	6.0	5	10	2	2	10	14	4.0		FILL	some silt
	SS-4	6.0	8.0	1	10	16	12	22		6.0			Grey-black sand and gravel FILL with silt, medium dense wet.
	SS-5	8.0	10.0	6	10	22	32	24	24		10.0		
10	SS-6	10.0	12.0	3	8	3	2	14					Grey sandy SILT, trace coarse sand, loose, saturated
	SS-7	12.0	14.0	1	0	1	0	18	50				Grey SILT, little fine sand, very loose, saturated
15	SS-8	14.0	16.0	Rod Weight				17				ML	
20	SS-9	18.0	20.0	1	1	1	1	16	33				trace low plasticity clay, trace fine sand
											22'6"		
													Dark grey SILTY CLAY, trace fine sand, medium to high plasticity, soft, wet
25	SS-10	23.0	25.0	1	2	2	1	18				CL	
											26.5		
													Grey fine to medium grained SAND, trace coarse sand, very loose, saturated
30	SS-11	28.0	30.0	1	0	0	0	3	18				
35	SS-12	33.0	35.0	5	8	12	14	11				SP	medium dense
40	SS-13	38.0	40.0	8	10	11	12	11	13				

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-3.XLS

HARD HAT SERVICES™
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BORING LOG

PROJECT No. 154.002.008.001
BORING No. BH-B-1 **(BH-3)**
LOGGED BY LES

PROJECT NAME: Alliant Energy - Baghouse Geotechnical Investigation
BORING LOCATION: Burlington, Iowa
DRILLER: RDnP Drilling - Chris
DATE: START 7/15/2008 FINISH 7/21/2008

DEPTH	SAMPLE No.	INTERVAL FROM	INTERVAL TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	USCS SOIL TYPE	SOIL DESCRIPTION
												SP	Grey fine to medium SAND, trace coarse sand, medium dense, saturated
45	SS-14	43.0	45.0	5	10	14	22	11					
50	SS-15	48.0	50.0	9	14	16	16	12	15				
55	SS-16	53.0	55.0	8	12	14	15	11					
60	SS-17	58.0	60.0	10	11	18	24	10	13				several pieces of coarse grained gravel at 58.5'
65	SS-18	63.0	65.0	15	24	26	36	10					dense
											66.5	SW	Grey fine to coarse SAND and fine grained gravel, very dense, saturated
70	SS-19	68.0	70.0	32	32	38		12	9				
75	SS-20	73.0	75.0	32	75/3			4					
											76.5	GP	Fine GRAVEL with fine to coarse sand, very dense, saturated
80	SS-21	78.0	80.0	50	100/3			4	8		79.5		Spoon bounced at 79.5'
													EOB at 80'

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-3.XLS

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BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-4**
LOGGED BY LES
PAGE No. 1 of 2

PROJECT NAME: Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION: Burlington, Iowa
SURFACE ELEVATION: 534.43
DRILLER: RDnP Drilling - Kris Norwick
DATE: START 12/2/2008 FINISH 12/3/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNTS 0"-6"	6"-12"	12"-18"	18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	3	4	5	15	16.0					FILL	Black and brown silty clay FILL, some fine sand, dry
5	SS-2	4.0	6.0	9	8	11	12	17.0						Black and brown fine to coarse sand and fine gravel FILL, trace fines, wet
	SS-3	6.0	8.0	10	5	12	15	20.0			6'6"	527.93		
	SS-4	8.0	10.0	2	2	3	20	24.0					ML	Grey SILT, little fine sand, medium dense, saturated loose 4" fine sand seam at 9'6"
10														
											11'6"	522.93	CL	Grey SILTY-CLAY, trace fine sand, medium plasticity, soft, moist to wet
	SS-5	13.0	15.0	2	2	3	4	14.0	50	2.00				
15														
	SS-6	18.0	20.0	7	9	8	11	15.0			18'4"	516.10	SP	Grey-brown fine to coarse SAND, medium dense, wet
20														
	SS-7	23.0	25.0	10	11	15	15	12.0	18					
25														
	SS-8	28.0	30.0	6	10	12	14	11.0						
30														
														trace fine gravel
	SS-9	33.0	35.0	6	7	9	11	11.0	19					
35														
											36'6"	497.93	SW	Brown fine to coarse SAND, little fine gravel, trace silt, medium dense, wet
	SS-10	38.0	40.0	7	9	7	10	10.0						
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-4.XLS

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-4**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.43
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/2/2008 FINISH 12/3/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														(cont.) Brown fine to coarse SAND, little fine gravel, medium dense, wet
	SS-11	43.0	45.0	5	6	6	8	11.0	14					
45														
	SS-12	48.0	50.0	12	12	16	19	10.0						
50														
	SS-13	53.0	55.0	8	9	11	14	12.0	13				SW	
55														
	SS-14	58.0	60.0	10	8	10	13	12.0						
60														
	SS-15	63.0	65.0	18	21	32	50/5	16.0	11					very dense
65														
											64'6"	469.93		Grey silty CLAY, trace fine sand, medium plasticity, hard, wet
	SS-16	68.0	70.0	21	32	42	44	24.0		+4.5			CL	
70														
	SS-17	73.0	75.0	10	17	22	23	20.0	25					
75											75'	459.43		EOB 75'
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-5**
LOGGED BY LES
PAGE No. 1 of 2

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.71
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/4/2008 FINISH 12/5/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	15	19	22	23	12.0						Black and brown sand and gravel FILL, some fines, wet
5	SS-2	4.0	6.0	10	19	34	50/3	16.0					FILL	
	SS-3	6.0	8.0	32	32	22	8	18.0						Brown-grey silt with sand FILL
	SS-4	8.0	10.0	9	12	23	14	20.0						6" brown-red fine to coarse sand FILL
10	SS-5	10.0	12.0	1	2	4	1	24.0			10'	524.71	ML	Grey SILT, little fine sand, loose, wet
											13'	521.71		
	SS-6	13.0	15.0	1	1	2	3	21.0	36					Mottled green, black, and light grey SILTY CLAY, little fine sand, trace silt and wood pieces, medium stiff, wet
15														
	SS-7	18.0	20.0	2	2	3	3	13.0	34	1.00			CL	
20														
	SS-8	23.0	25.0	5	7	7	9	14.5			23'2"	511.54		Black and brown fine to medium SAND, trace coarse sand, medium dense, wet 23'7" grey
25														
	SS-9	28.0	30.0	3	4	6	7	13.0	19					
30													SP	
	SS-10	33.0	35.0	7	7	9	11	12.0						
35														
	SS-11	38.0	40.0	7	10	11	14	14.0	22					5" fine sand seam 2" coarse sand and fine gravel seam
40														

Drilled with Dietrich -120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-5**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.71
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/4/2008 FINISH 12/5/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	6"-12"	12"-18"	18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														(cont.) Grey fine to medium SAND, trace coarse sand, wet
	SS-12	43.0	45.0	12	15	22	26	13.5						dense
45														
	SS-13	48.0	50.0	10	12	12	15	12	17				SP	medium dense
50														
	SS-14	53.0	55.0	5	15	21	15	13						dense, 53'6" - 1" gravel piece
55														
														medium dense
	SS-15	58.0	60.0	6	8	11	15	10	12		58'7"	476.13		Grey fine to coarse SAND, some fine gravel, very dense
60														
	SS-16	63.0	65.0	50/0				0					SW	
65														(rig was grinding heavily to get from 65' to 68')
	SS-17	68.0	70.0	50/4				4						
70											70'	464.71		EOB 70'
75														
80														

Drilled with Dietrich -120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-6**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.33
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/4/2008 FINISH 12/5/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	10	11	15	17	17.0						Brown silty sand FILL, trace medium sand, medium dense
5	SS-2	4.0	6.0	1	3	5	11	13.0					FILL	
	SS-3	6.0	8.0	50/5				7.5						(possibly gravel inhibiting sampling)
	SS-4	8.0	10.0	41	50/3			5.5						
10											10'	524.33		
	SS-5	10.0	12.0	3	2	1	4	20.0	49					Brownish-grey SILT, trace fine sand, very loose, saturated
	SS-6	13.0	15.0	3	4	4	5	24.0	53				ML	loose
15														
											16'6"	517.83		Brownish-grey SILTY CLAY, trace fine sand, soft, wet
	SS-7	18.0	20.0	1	1	1	2	17.0	49	0.50				
20													CL	
	SS-8	23.0	25.0	1	3	4	5	16.0			24'	510.33		Brown fine to medium SAND, trace coarse sand, medium dense, wet
25														
	SS-9	28.0	30.0	6	7	9	11	15.5	18					
30													SP	
	SS-10	33.0	35.0	10	11	14	14	12.0						
35														
											36'6"	497.83		Brown fine to coarse SAND, little fine gravel, medium dense, wet
	SS-11	38.0	40.0	6	8	9	12	12.5	9				SW	
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BORING LOG

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

PROJECT No. 154.002.008.001
BORING No. **BH-6**
LOGGED BY LES
PAGE No. 2 of 2

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.33
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/4/2008 FINISH 12/5/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
													SW	Brown fine to coarse SAND, little fine gravel, medium dense, wet (cont.)
											42'6"	491.83		Brown fine to medium sand, trace fine sand, medium dense to dense, wet (cont.)
	SS-12	43.0	45.0	8	10	14	17	12.0						
45														
	SS-13	48.0	50.0	8	9	12	14	12.0	14					little coarse sand
50													SP	
	SS-14	53.0	55.0	10	17	17	15	12.5						
55														
	SS-15	58.0	60.0	10	12	14	14	10.0	14					
60														
											62' 6"	472.00		Grey SILTY CLAY, little fine to medium sand, medium plasticity, hard, wet
	SS-16	63.0	65.0	17	31	36	42	22.0	14	4.5+ 4.5+				1" fine to medium sand seam at 63'6" 1" gravel piece at 6'8"
65													CL	
	SS-17	68.0	70.0	21	50/3			9.0		4.5+				
70											70'	464.33		EOB 70'
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-6.XLS

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-7**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 536.51
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/5/2008 FINISH 12/8/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	6"-12"	12"-18"	18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	6	7	10	12	22.5		1.00			FILL	Black sand, gravel, and silt FILL 6" alternating brown and black fine sand and silt at 3'
5	SS-2	4.0	6.0	1	3	10	14	15.0		0.75				6"grey clay, medium stiff, moist at 4'
	SS-3	6.0	8.0	10	31	21	33	18.0			6'	530.51		Dark grey SILT, some fine sand, very dense, wet
	SS-4	8.0	10.0	15	21	18	15	17.0						
10	SS-5	10.0	12.0	10	22	32	44	21.0					ML	trace fine sand
	SS-6	13.0	15.0	3	4	1	5	23.0	67					loose
15														
											16'6"	520.01		Grey SILTY CLAY, trace fine sand, very soft, wet
	SS-7	18.0	20.0	1	2	1	2	24.0					CL	
20														
											23'6"	513.01		Grey fine to medium SAND with clay, loose, wet
	SS-8	23.0	25.0	1	2	4	12	16.0	19				SP-SC	
25														
											26'6"	510.01		Grey fine to medium SAND, medium dense, wet
	SS-9	28.0	30.0	2	5	8	8	18.0						
30														
	SS-10	33.0	35.0	8	14	16	15	12.0	17				SP	trace coarse sand
35														
	SS-11	38.0	40.0	8	14	10	8	12.0						medium dense
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-7.XLS

BORING LOG

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

PROJECT No. 154.002.008.001
BORING No. **BH-7**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 536.51
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/5/2008 FINISH 12/8/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Grey fine to medium SAND, trace coarse sand medium dense, wet
	SS-12	43.0	45.0	5	8	10	11	12.0	15					
45														
	SS-13	48.0	50.0	8	10	15	18	14.0					SP	
50														
	SS-14	53.0	55.0	10	12	15	16	10.0	15					
55														
											56'6"	480.01		Brown fine to coarse SAND, trace fine gravel, medium dense, wet
	SS-15	58.0	60.0	8	11	15	17	24.0						
60													SW	
	SS-16	63.0	65.0	18	23	50/4		10.0	7					very dense
65											65'	471.51		EOB 65'
70														
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-8**
LOGGED BY LES
PAGE No. 1 of 2

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa SURFACE ELEVATION 534.72
DRILLER RDnP Drilling - Kris Norwick DATE: START 12/15/2008 FINISH 12/17/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	6"-12"	12"-18"	18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	8	12	10	12	18.0						Brown and grey mottled silty clay FILL, little fine to coarse sand, medium dense, frozen
5	SS-2	4.0	6.0	3	4	6	6	16.0		1.75			FILL	
	SS-3	6.0	8.0	3	5	7	10	10.0						fine gravel pieces mixed in clay
	SS-4	8.0	10.0	3	4	6	9	15.0	17	2.50				
10	SS-5	10.0	12.0	4	5	7	4	14.0	23	3.00	10'6"	524.22		Grey SILT, trace fine sand, medium dense to loose, wet
	SS-6	13.0	15.0	2	3	3	3	8.0	26				ML	alternating silt and brown silty clay, stiff
15											16'6	518.22		Grey SILTY CLAY, medium plasticity, medium stiff, mois to wet (LL=46, PI=24)
	SS-7	18.0	20.0	1	2	3	2	10.0	34	1.25			CL	
20											23'3"	511.47		Brown fine to medium SAND, loose, wet
	SS-8	23.0	25.0	5	6	7	7	12.0						
25														
	SS-9	28.0	30.0	2	5	4	5	24.0	20					
30													SP	trace coarse sand
	SS-10	33.0	35.0	2	3	4	5	12.0						
35														
	SS-11	38.0	40.0	4	5	5	7	11.5	12					
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES ™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-8**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.72
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/15/2008 FINISH 12/17/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Brown fine to medium SAND, trace coarse sand, medium dense, wet (cont.)
	SS-12	43.0	45.0	9	10	11	15	11.0						
45													SP	
	SS-13	48.0	50.0	14	17	9	7	13.0	16					
50														
											49'6"	485.22		Brown fine to coarse SAND, trace fine gravel, medium dense, wet
	SS-14	53.0	55.0	4	8	7	6	13.0						
55														
	SS-15	58.0	60.0	8	15	19	22	15.0	8				SW	dense
60														
	SS-16	63.0	65.0	5	15	24	26	17.0						little fine gravel
65														
											66'6"	468.22		Grey sandy SILTY CLAY, hard, moist to wet
	SS-17	68.0	70.0	48	50/4			13.0	14				CL	
70											70'	464.72		EOB 70'
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-9**
LOGGED BY LES
PAGE No. 1 of 2

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.67
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/17/2008 FINISH 12/18/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	3	4	2	2	14.0		2.50				Grey and brown mottled silty clay FILL, some fine to medium sand, very stiff, moist
5	SS-2	4.0	6.0	3	4	6	5	17.0		4.00			FILL	
	SS-3	6.0	8.0	4	5	5	8	17.0		2.50				Alternating grey, brown, and orange clay and silt
	SS-4	8.0	10.0	4	5	10	10	17.0		2.00	8'11"	525.75		
10	SS-5	10.0	12.0	5	7	9	12	16.0		4.00			CL	Grey SILTY CLAY, trace fine sand, medium plasticity, very stiff, moist
	SS-6	13.0	15.0	3	4	6	6	21.0			13'	521.67		Dark grey CLAY, high plasticity, stiff, wet
15														
	SS-7	18.0	20.0	3	3	4	5	21.0	51	1.00				(LL=64, PI=34)
20													CH	
	SS-8	23.0	25.0	5	6	8	9	0.0						
25														(hole is taking a lot of water)
											24'6"	510.17		Grey fine to medium SAND, medium dense, wet
	SS-9	28.0	30.0	8	10	12	14	10.0	25					
30														
	SS-10	33.0	35.0	8	15	19	22	16.0					SP	trace coarse sand, dense
35														
	SS-11	38.0	40.0	10	16	17	19	11.0	18					
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-9.XLS

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-9**
LOGGED BY LES

PROJECT NAME: Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION: Burlington, Iowa
SURFACE ELEVATION:
DRILLER: RDnP Drilling - Kris Norwick
DATE: START 12/17/2008 FINISH 12/18/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Grey fine to medium SAND, trace coarse sand, dense, wet
	SS-12	43.0	45.0	10	17	24	29	8.0						trace fine gravel
45														
	SS-13	48.0	50.0	8	16	20	21	12.0	17				SP	
50														
	SS-14	53.0	55.0	9	11	15	19	13.0						
55														
											56'6"	478.17		Grey-brown fine to coarse SAND, trace fine gravel, dense, wet
	SS-15	58.0	60.0	10	12	18	17	16.0	17					
60													SW	
	SS-16	63.0	65.0	12	15	24	26	15.0						dense
65														
											66'6"	468.17		Grey CLAY, little fine to medium sand, medium plasticity, hard, moist to wet
	SS-17	68.0	70.0	37	50/4			10.0					CL	
70											70'	464.67		EOB 70'
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES ™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-10**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 531.92
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/12/2008 FINISH 12/15/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	4	5	5	4	13.0	17	2.00				Grey and brown mottled SILTY CLAY, trace fine sand, medium plasticity, stiff, moist
5	SS-2	4.0	6.0	3	4	5	6	15.0	15	2.50				little fine to coarse sand, very stiff
	SS-3	6.0	8.0	4	4	5	6	15.0	13	2.50			CL	
	SS-4	8.0	10.0	3	6	8	8	15.0	24	2.50 1.50				Brown, silt content increasing, thin brown silt seams
10														
	SS-5	13.0	15.0	1	2	3	4	15.0		0.75 1.00	13'	518.92		Dark grey CLAY, high plasticity, medium stiff, wet
15														
	SS-6	18.0	20.0	4	6	5	7	13.5		1.25				stiff
20													CH	
	SS-7	23.0	25.0	3	4	5	5	6.0		1.00				
25														
	SS-8	28.0	30.0	8	9	11	12	0.0			29'	502.92		Grey-brown fine to medium SAND, medium dense, wet
30														
	SS-9	33.0	35.0	6	8	5	5	10.0						
35														
	SS-10	38.0	40.0	8	9	11	12	11.0						trace coarse sand
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-10**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa SURFACE ELEVATION 531.92
DRILLER RDnP Drilling - Kris Norwick DATE: START 12/12/2008 FINISH 12/15/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Grey-brown fine to medium SAND, trace coarse sand, medium dense, wet (cont.)
	SS-11	43.0	45.0	3	6	9	15	15.0						
45														
														dense
	SS-12	48.0	50.0	8	15	21	30	15.0						
50														
													SP	(spoon bouncing, possibly on a cobble or boulder)
	SS-13	53.0	55.0	50/0				0.0						
55														
														trace fine gravel
	SS-14	58.0	60.0	14	17	17	15	16.0						
60														
	SS-15	63.0	65.0	50/1				0.0			64'	467.92		Grey CLAY, little fine sand, hard, moist to wet
65														
													CL	
	SS-16	68.0	70.0	32	50/3			10.0		4.5+				(spoon bouncing)
70											70'	461.92		EOB 70'
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

APPENDIX B – Geoprobe Soil Borings on CCR Embankments

Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

Structural Stability Assessment

Boring Log Legend

Sample
No: (Number) Soil samples are numbered consecutively from the ground surface. Core samples are numbered consecutively from the first core run.

Type: A= Auger Cuttings CR= Core Run MS= Modified Spoon PB= Pitcher Barrel
PT= Piston Tube ST= Shelby Tube SS= Split Spoon (2" O.D.) WC= Wash Cuttings

Interval: The depth of sampling interval in feet below ground surface

Blow Count
The number of blows required to drive a 2-inch O.D. split-spoon sampler with a 140 pound hammer falling 30-inches. When appropriate, the sampler is driven 18 inches and blow counts are reported for each 6-inch interval. The sum of blow counts for the last two 6-inch intervals is designated as the standard penetration resistance (N) expressed as blows per foot.

Recovery in Inches
The length of sample recovered by the sampling device.

U.S.C.S. Soil Type
The Unified Soil Classification System symbol for recovered soil samples determined by visual examination or laboratory tests. Refer to ASTM D2487-69 for a detailed description of procedure and symbols. Underlined symbols denote classifications based on laboratory tests (i.e. ML), all others are based on visual classification only.

Percent Moisture
Natural moisture content of sample expressed as percent of dry weight.

q_u TSF
Unconfined compressive strength in tons per square foot obtained by hand penetrometer. Laboratory compression test values are indicated by underlining.

Contact Depth
The contact depth between soil layers is interpreted from significant changes in recovered samples and observations during drilling. Actual changes between soil layers often occur gradually and the contact depths shown on the boring logs should be considered as approximate.

Soil Description and Remarks
Soil descriptions include consistency or density, color, predominant soil types and modifying constituents.

Cohesive Soils			Cohesionless Soils	
Consistency	q_u (TSF)	Blows/ft.	Density	Blows/ft.
Very Soft	less than 0.25	0-1	Very Loose	4 or less
Soft	0.25 to 0.50	2-4	Loose	5 to 10
Medium Stiff	0.50 to 1.00	5-8	Medium Dense	11 to 30
Stiff	1.00 to 2.00	9-15	Dense	30 to 50
Very Stiff	2.00 to 4.00	15-30	Very Dense	Over 50
Hard	more than 4.00	Over 30		

Particle Size Description

Boulder =	Larger than 12 inches
Cobble =	3 to 12 inches
Gravel =	0.187 to 3 inches
Sand =	0.074 to 4.76 mm
Silt and Clay =	smaller than 0.074 mm

Definition of Terms

Trace =	5 to 12 percent by weight
Some =	12 to 30 percent by weight
And =	Approximately equal fractions
( ) =	Driller's observation

Piezo.
(Piezometer) Screened interval of the piezometer installation is denoted by cross-hatching.

General Note
The boring log and related information depicted subsurface conditions only at the specified locations and date indicated. Soil conditions and water levels at other locations may differ from conditions occurring at these boring locations. Also the passage of time may result in a change in the conditions at these boring locations.

Soil Test Boring Refusal
Defined as any material causing a blow count greater that 50 blows/6 inches. Such material may include bedrock, "floating" rock slabs, boulders, dense gravel seams, hard pan clay, or cemented soils. Refusal is usually indicated in fractional notation showing number of blows as the numerator and inches of penetration as the denominator.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SB1 (CPT1)*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-11-11*
DATE FINISHED: *05-11-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	2.5'/5'		
	SP2	5'/5'		
	SP3	5'/5'		
	SP4	5'/5'		
▽	SP5	0'/5'		
	SP6	5'/5'		
	SP7	1.5'/5'		2.75 2.75 3.25 3.75 1.5
	SP8	5'/5'		

CONSISTENCY vs. DEPTH | DEPTH IN FEET: 0, -5, -10, -15, -20, -25, -30, -35, -40, -45 | PROFILE

DESCRIPTION

ASH; brown; poorly graded; fine grained; moist. (Fill)

@ 14' grades dark gray to black.

Clayey SILT; black to gray; non-plastic to low plasticity; moist to wet; some organic matter. (OL)
@ too soft for pocket penn from 19.5' to 31', no hammer required to push sampler.

CLAY; gray to black; high plasticity; soft to firm; moist; trace organic. (OH)

Sandy SILT; gray; non-plastic; wet. (ML)

SAND; gray; well graded; fine to coarse grained; rounded to sub-rounded; wet. (SW)

Bottom of Boring @ 40'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-11-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

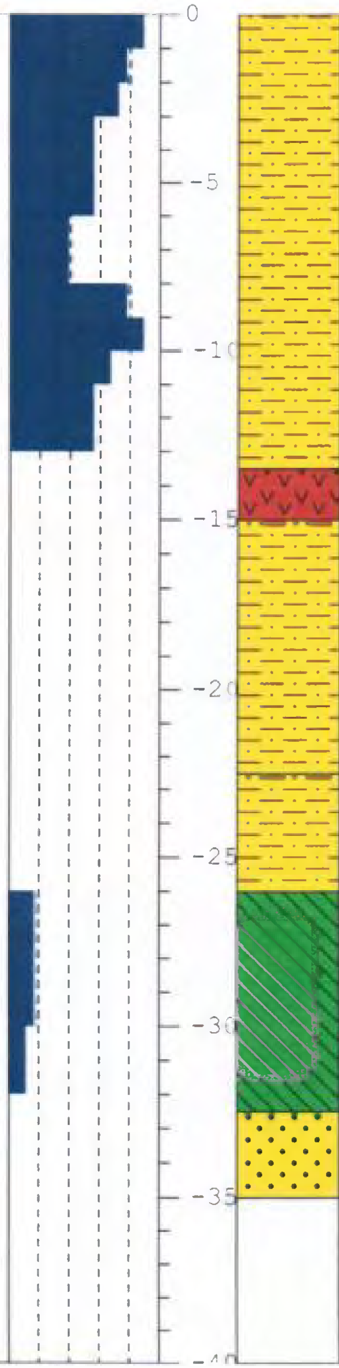
COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*

BORING NO.: ***SB2 (CPT7)***

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-11-11*
DATE FINISHED: *05-11-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	5'/5'		4.0, 3.5, 3.25, 2.5, 2.5
	SP2	5'/5'		2.5, 1.75, 1.75, 3.5, 4.0
	SP3	5'/5'		3.0, 2.5, 2.5
	SP4	4'/5'		
▽	SP5	4'/5'		
	SP6	5'/5'		0.75, 0.75, 0.75, 0.75, 0.5, 0.5
	SP7	4'/5'		

CONSISTENCY vs. DEPTH / DEPTH IN FEET / PROFILE



DESCRIPTION

Clayey SILT; brown to gray; non-plastic; firm to stiff; dry to moist; trace roots/organic matter. (Fill)

ASH; black; non-plastic; moist. (FILL)

Clayey SILT; gray to black; non-plastic; trace organic matter/shells. (OL)

SILT; gray; non-plastic; wet. (ML)

CLAY; gray to black; soft; high plasticity; moist; trace to some organic matter. (OH)

SAND; gray; poorly graded; medium grained; wet. (SP)

Bottom of boring @ 35'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-11-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

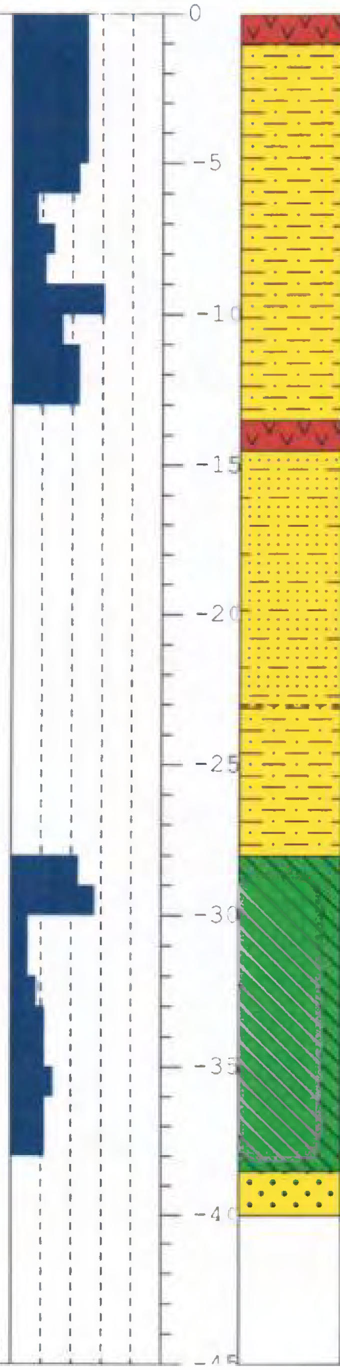
COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*

BORING NO.: *SB3 (CPT10)*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-11-11*
DATE FINISHED: *05-11-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	3.5'/5'		2.25, 2.25, 2.25, 2.25, 2.25
	SP2	5'/5'		2.0, 0.75, 1.25, 1.0, 2.75
▽	SP3	5'/5'		1.5, 2.0, 2.0
	SP4	5'/5'		
	SP5	5'/5'		
	SP6	5'/5'		2.0, 2.5, 0.5, 0.5
	SP7	5'/5'		0.75, 1.0, 1.0, 1.25, 1.0
	SP8	5'/5'		1.0, 1.0

CONSISTENCY vs. DEPTH | DEPTH IN FEET | PROFILE



DESCRIPTION

ASH; brown; non-plastic; moist. (FILL)

Clayey SILT; brown to gray; non-plastic; firm to stiff; dry to moist; trace roots/organic matter. (Fill)

ASH; gray; non-plastic; moist. (FILL)

Silty SAND; dark gray to light gray; poorly graded; fine grained; wet. (SP)

SILT; gray; non-plastic; wet. (ML)

Silty CLAY; gray to black; soft; low plasticity; moist; trace to some organic matter. (OH)

SAND; gray; poorly graded; fine grained; wet. (SP)

Bottom of boring @ 40'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-11-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

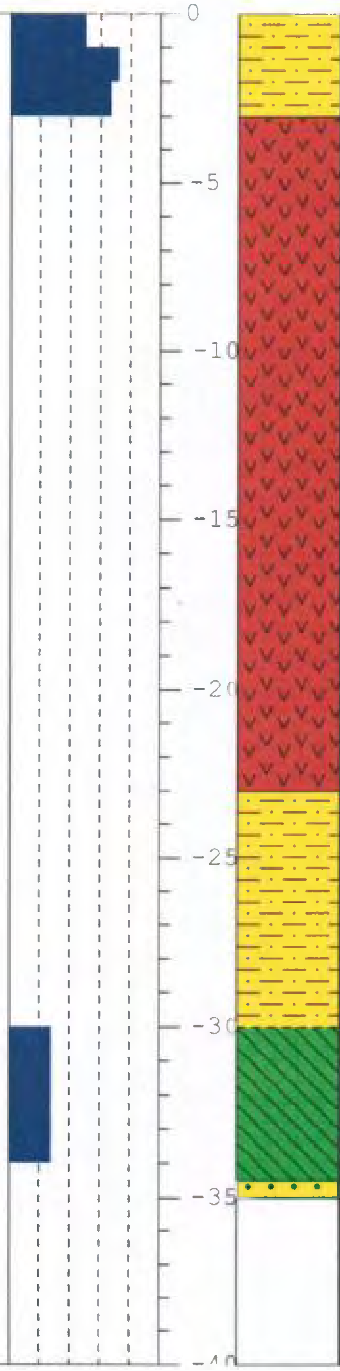
COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: ***SB4 (CPT6)***

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-11-11*
DATE FINISHED: *05-11-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	4.5'/5'		2.25 3.25 3.0
	SP2	5'/5'		
	SP3	5'/5'		
	SP4	5'/5'		
▽	SP5	3.5'/5'		
	SP6	4'/5'		
	SP7	5'/5'		1.25 1.25 1.25 1.25

CONSISTENCY vs. DEPTH | DEPTH IN FEET | PROFILE



DESCRIPTION

Clayey SILT; brown to gray; non-plastic; firm to stiff; dry to moist; trace roots/organic matter. (Fill)

ASH; gray; non-plastic; moist. (FILL)

SILT; gray; non-plastic; wet. (ML)

CLAY; gray to black; low to high plasticity; wet; some organic matter. (OL/OH)

SAND; gray; poorly graded; fine grained; wet. (SP)

Bottom of boring @ 35'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-11-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

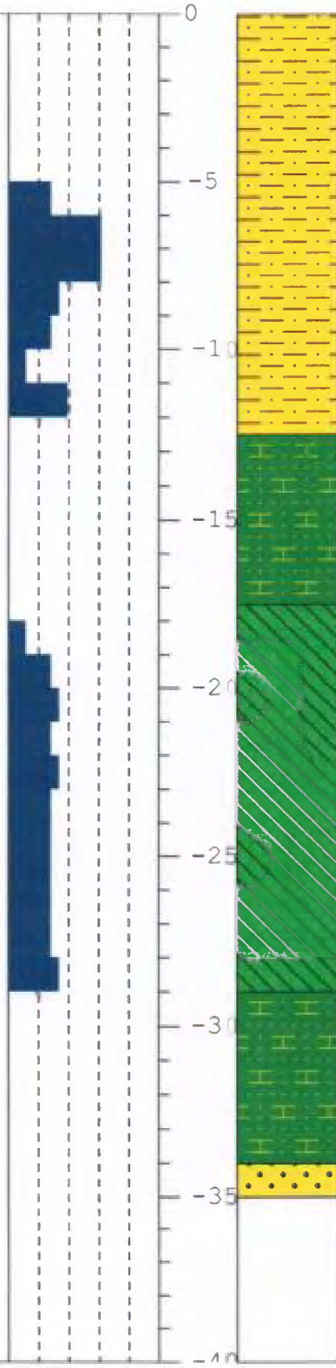
COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: ***SB5 (cpt19)***

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	5'/5'		
				1.25
				2.75
	SP2	5'/5'		2.75
				1.5
				1.25
				0.5
				1.75
				2.0
	SP3	4'/5'		
	SP4	4'/5'		
				0.5
				1.25
				1.5
				1.25
	SP5	3.5'/5'		1.5
				1.25
				1.25
				1.25
				1.25
				1.25
	SP6	3.5'/5'		1.5
▽				1.25
	SP7	3'/5'		

CONSISTENCY vs. DEPTH / DEPTH IN FEET / PROFILE



DESCRIPTION

SILT; brown; non-plastic; dry to moist; trace organic matter. (Fill)

@ 5' grades Clayey SILT; low plasticity; firm to stiff.

Sandy CLAY; black to dark gray; non-plastic to low plasticity; moist. (CL)

CLAY; black to dark gray; low to high plasticity; moist; trace organic matter. (CL)

Sandy CLAY; dark gray; low to high plasticity; wet; trace silt. (CL)

@ 33' grades several thin sand seams.

SAND; gray; poorly graded; coarse grained; wet. (SP)

Bottom of boring @ 35'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

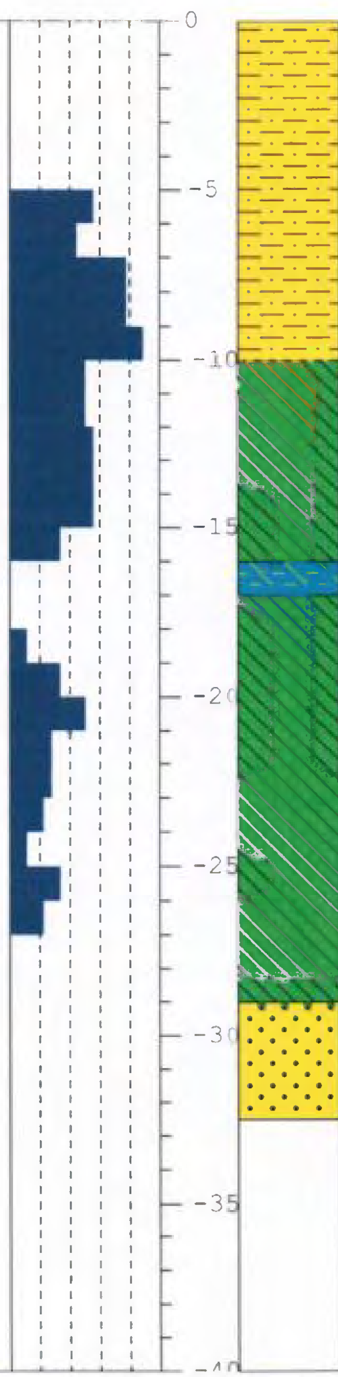
PROJECT: Burlington, IA

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SB6 (cpt18)*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	5'/5'		
	SP2	5'/5'		2.5, 2.0, 3.5, 3.5, 4.0
	SP3	5'/5'		2.25, 2.25, 2.5, 2.5, 2.5
▽				2.5, 1.5
	SP4	4.5'/5'		0.5, 1.5, 2.25, 1.25
	SP5	2.5'/5'		1.25, 1.0, 0.5, 1.5, 1.0
	SP6	3.8'/5'		0, 0, 0
	SP7	2.5'/2.5'		



DESCRIPTION

SILT; brown; non-plastic; dry to moist; trace organic matter (FILL)

@ 5' grades Clayey SILT; low plasticity; very stiff.

CLAY; gray to olive; low to high plasticity; stiff to very stiff; moist; trace organic matter (Fill)

Clayey SAND; gray; poorly graded; medium grained; wet. (SP)

CLAY; gray to olive; high plasticity; very soft to firm; moist to wet. (CL)

@ 19' is a thin 1" sand seam, wet.

SAND; gray; well graded; fine to coarse grained; wet. (SW)

Bottom of boring @ 32.5'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

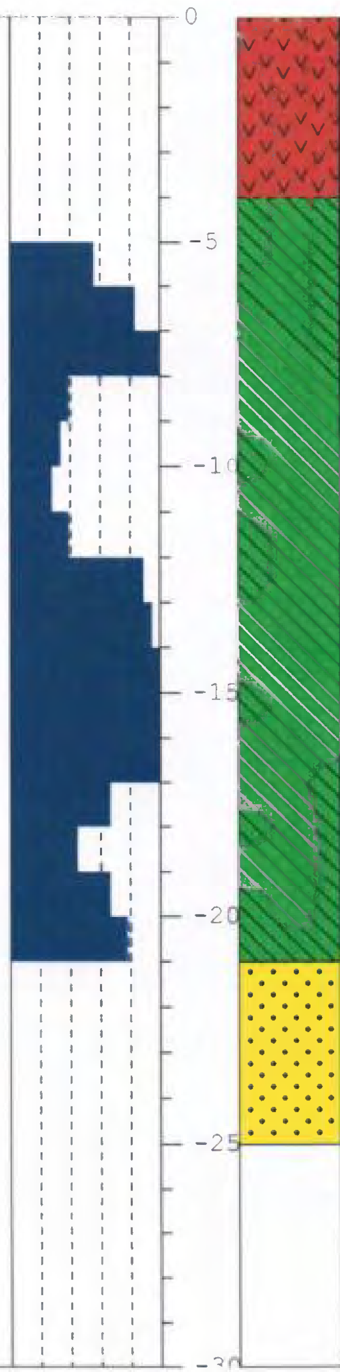
COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SB7 (cpt15)*

LOGGED BY:	*John Noyes*
EDITED BY:	*John Noyes*
CHECKED BY:	*Chris Sullivan*
DATE BEGAN:	*05-16-11*
DATE FINISHED:	*05-16-11*
GROUND SURFACE ELEVATION:	

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	3.8'/5'		
				2.5
				3.75
				>4.5
	SP2	5'/5'		1.75
				1.5
				1.25
				1.75
				4.0
	SP3	5'/5'		4.25
				4.5
				4.5
				>4.5
				3.0
	SP4	5'/5'		2.0
▽				3.0
				3.5
	SP5	3'/5'		

CONSISTENCY vs. DEPTH / DEPTH IN FEET / PROFILE



DESCRIPTION

ASH; gray; fine grained; moist. (Fill)

CLAY; black; low plasticity; stiff to very stiff; moist; trace organic matter (Fill)

@ 18' grades (OH)

@ 19' is a 6-inch SAND seam; fine grained; wet.
@ 20' grades high plasticity.

SAND; gray; poorly graded; fine grained; wet. (SW)

Bottom of boring @ 25'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

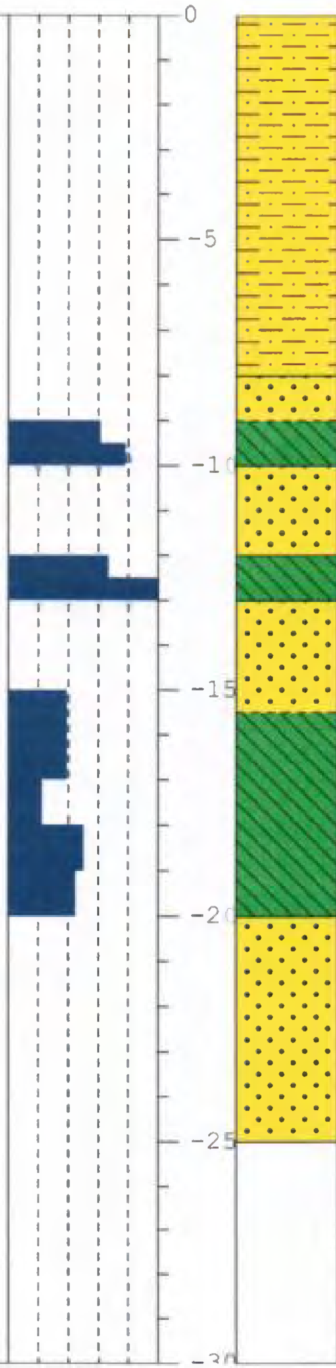
PROJECT: Burlington, IA

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: ***SB8 (cpt13)***

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	4'/5'		
▽	SP2	4'/5'		2.75 3.5
	SP3	5'/5'		3.0 4.5
	SP4	4'/5'		1.75 1.75 1.0 2.25 2.0
	SP5	4.5'/5'		



DESCRIPTION

SILT; brown; non-plastic; dry to moist; trace to some gravel, sand & ash. (Fill)

SAND; gray; fine grained; poorly graded; wet.(SP)

CLAY; gray; low to high plasticity; stiff; moist. (CL)

SAND; gray to black; fine grained; poorly graded; wet. (SP)

CLAY; gray; low to high plasticity; stiff; moist. (CL)

SAND; gray; well graded; fine to coarse grained; wet. (SW)

CLAY; dark gray; high plasticity; firm to stiff; moist; trace organic matter. (OH)

SAND; gray to black; poorly graded; fine grained; wet. (SP)

Bottom of boring @ 25'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

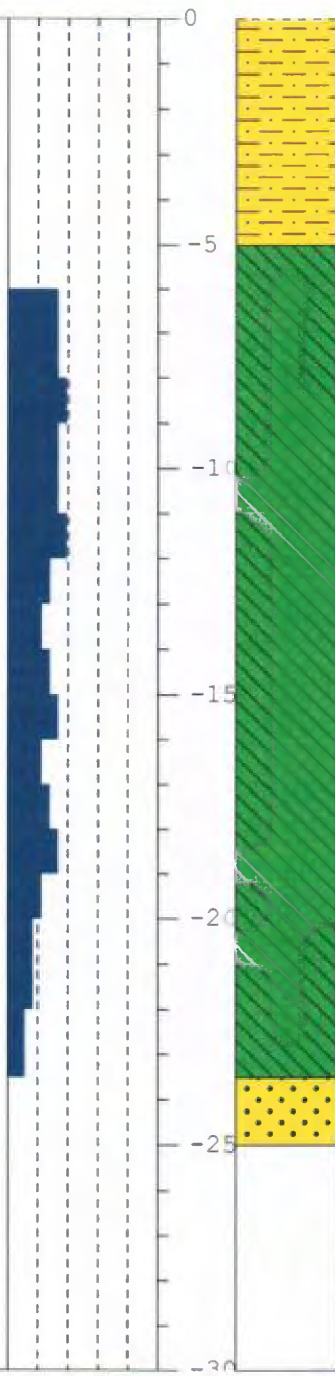
PROJECT: Burlington, IA

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SB9 (cpt21)*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	2.5'/5'		
				1.5
				1.5
	SP2	4'/5'		
				1.75
				1.5
				1.5
				1.75
				1.25
	SP3	4.5'/5'		
				1.0
				1.25
				1.5
				1.0
				1.25
	SP4	5'/5'		
				1.5
				1.0
				0.75
				0.75
				0.5
	SP5	3.5'/5'		
▽				0.5



DESCRIPTION

Depth (ft)	Description
0 to -5	SILT; brown; non-plastic; dry to moist; trace organic matter. (Fill)
-5 to ~-23.5	CLAY:gray to olive; low to high plasticity; moist; trace organics. (OH)
~-23.5 to -25	SAND; gray; fine grained; poorly graded; wet. (SP)

Bottom of boring @ 25'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

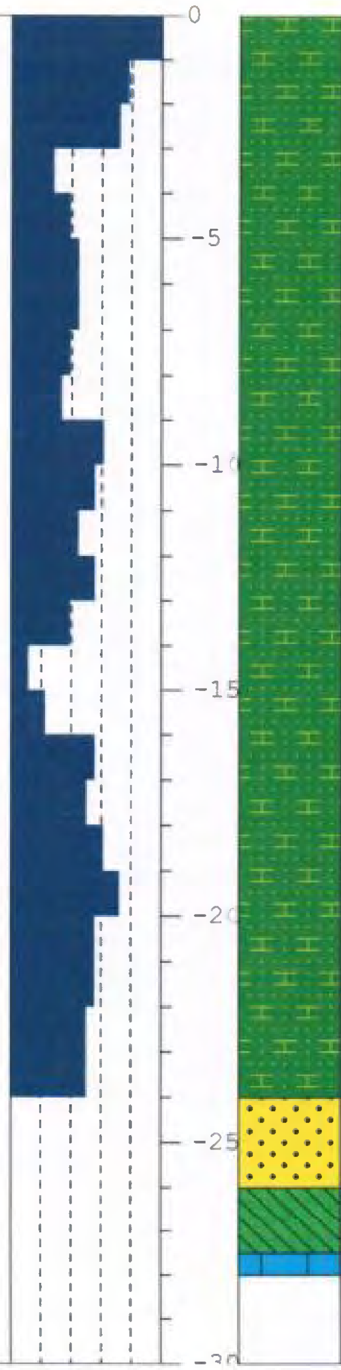
PROJECT: Burlington, IA

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SB10*

LOGGED BY:	*John Noyes*
EDITED BY:	*John Noyes*
CHECKED BY:	*Chris Sullivan*
DATE BEGAN:	*05-16-11*
DATE FINISHED:	*05-16-11*
GROUND SURFACE ELEVATION:	

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
				>4.5
				3.5
	SP1	2.5'/5'		3.25
				1.25
				1.75
				2.0
	SP2	4'/5'		2.0
				1.75
				1.5
				2.75
				2.5
	SP3	4.5'/5'		2.0
				2.5
				1.75
				0.5
				1.0
	SP4	5'/5'		2.5
				2.25
				2.75
				3.25
				2.5
	SP5	3.5'/5'		2.5
				2.25
▽				
	SP6	2'/3'		



DESCRIPTION

Silty CLAY; brown; low plasticity; firm to very stiff; moist; trace organics and gravels. (CL - OH)

SAND; gray to brown; well graded; fine to coarse grained; wet. (SW)

CLAY; gray; high plasticity; moist. (CL)

LIMESTONE; gray; thinly bedded; highly weathered. (Bedrock)

Bottom of boring @ 25'
Boring advanced W/ Geoprobe Model 6610DT using

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*

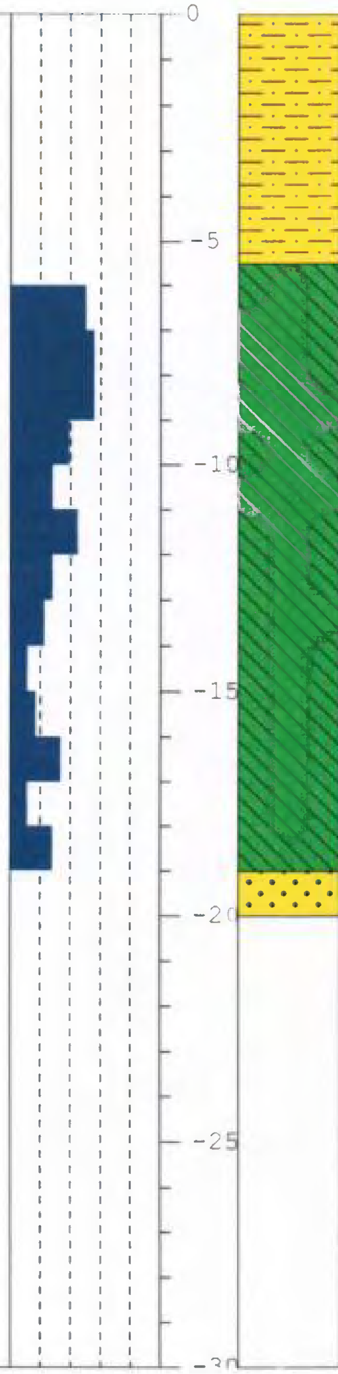
BORING NO.: *SB11*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION
	SP1	2.5'/5'	
	SP2	4'/5'	
	SP3	4.5'/5'	
▽			
	SP4	5'/5'	

POCKET PENETROMETER (TONS/FT2)
2.25
2.5
2.5
1.75
1.25
2.0
1.25
1.0
0.5
0.75
1.5
0.5
1.25
1.0

CONSISTENCY vs. DEPTH / DEPTH IN FEET / PROFILE



DESCRIPTION

Gravely SILT; brown; non-plastic; dry to moist. (Fill)

CLAY; brown; high plasticity; moist; stiff to soft; trace sand & gravel. (CL)

@ 11.5' grades black to gray, trace organics. (OH)

@ 14.5' are several thin, 1-inch, fine grained sand seams; wet.

SAND; gray; poorly graded; fine grained; wet. (SP)

Bottom of boring @ 20'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

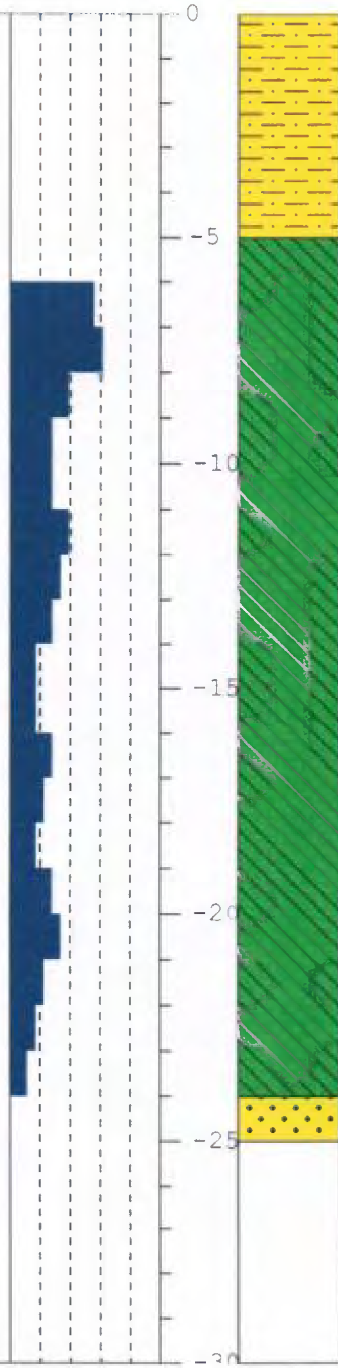
COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SB12*

LOGGED BY:	*John Noyes*
EDITED BY:	*John Noyes*
CHECKED BY:	*Chris Sullivan*
DATE BEGAN:	*05-16-11*
DATE FINISHED:	*05-16-11*
GROUND SURFACE ELEVATION:	

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	2.5'/5'		
				2.5
				2.75
	SP2	5'/5'		1.75
				1.25
				1.25
				1.75
				1.5
	SP3	5'/5'		1.25
				0.75
				0.75
				1.25
				1.0
	SP4	4.5'/5'		0.75
				1.25
				1.5
				1.0
	SP5	5'/5'		0.75
				0.5
▽				

CONSISTENCY vs. DEPTH / DEPTH IN FEET / PROFILE



DESCRIPTION

0 to -5: Gravely SILT; brown; non-plastic; dry to moist. (Fill)

-5 to -24: CLAY; brown; high plasticity; moist; stiff to soft; trace sand & gravel. (CL)

@ 14' grades dark gray to black; trace organics. (OH)

-24 to -25: SAND; black to dark gray; poorly graded; fine grained; wet. (SP)

Bottom of boring @ 25'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

APPENDIX C – CPT Soil Probes on CCR Embankments

Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

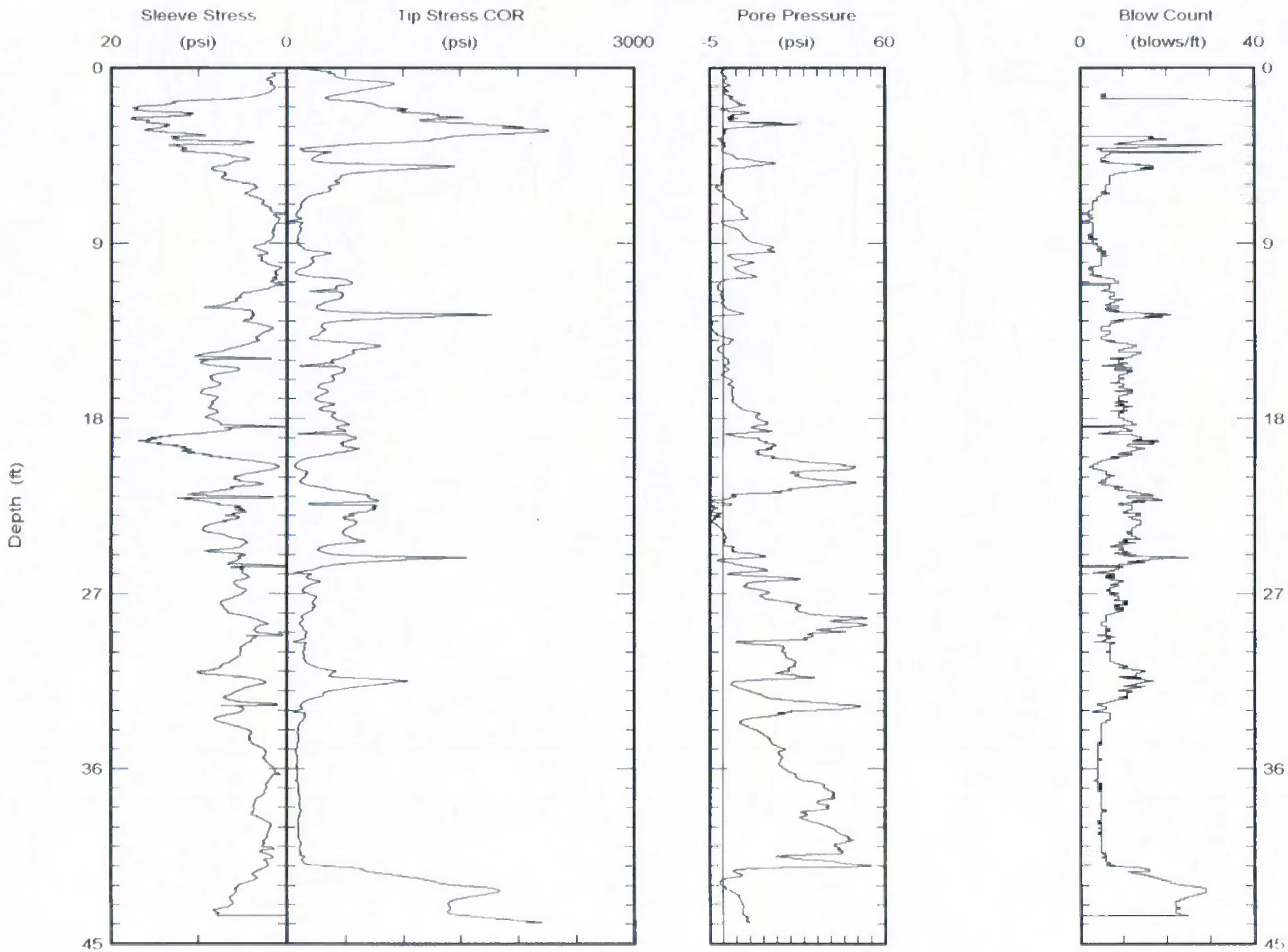
Safety Factor Assessment

CONE PENETROMETER TEST (CPT)

CPT I.D.	LOCATION	GROUND ELEVATION (FT)
CPT-1	Economizer Ash Pond	548.78
CPT-2	Economizer Ash Pond	550.34
CPT-3	Economizer Ash Pond	549.91
CPT-4	Economizer Ash Pond	549.65
CPT-5	Economizer Ash Pond	549.74
CPT-6	Economizer Ash Pond	550.57
CPT-7	Economizer Ash Pond	545.78
CPT-8	Economizer Ash Pond	546.26
CPT-9	Economizer Ash Pond	549.48
CPT-10	Economizer Ash Pond	549.42
CPT-11	Economizer Ash Pond	547.86
CPT-12	Economizer Ash Pond	548.25
CPT-13	Ash Seal Water Pond	534.22
CPT-14	Ash Seal Water Pond	533.67
CPT-15	Main Ash Pond	536.75
CPT-16	Main Ash Pond	534.84
CPT-17	Main Ash Pond	534.52
CPT-18	Main Ash Pond	533.89
CPT-19	Main Ash Pond	535.32
CPT-20	Upper Ash Pond	530.47
CPT-21	Upper Ash Pond	530.42

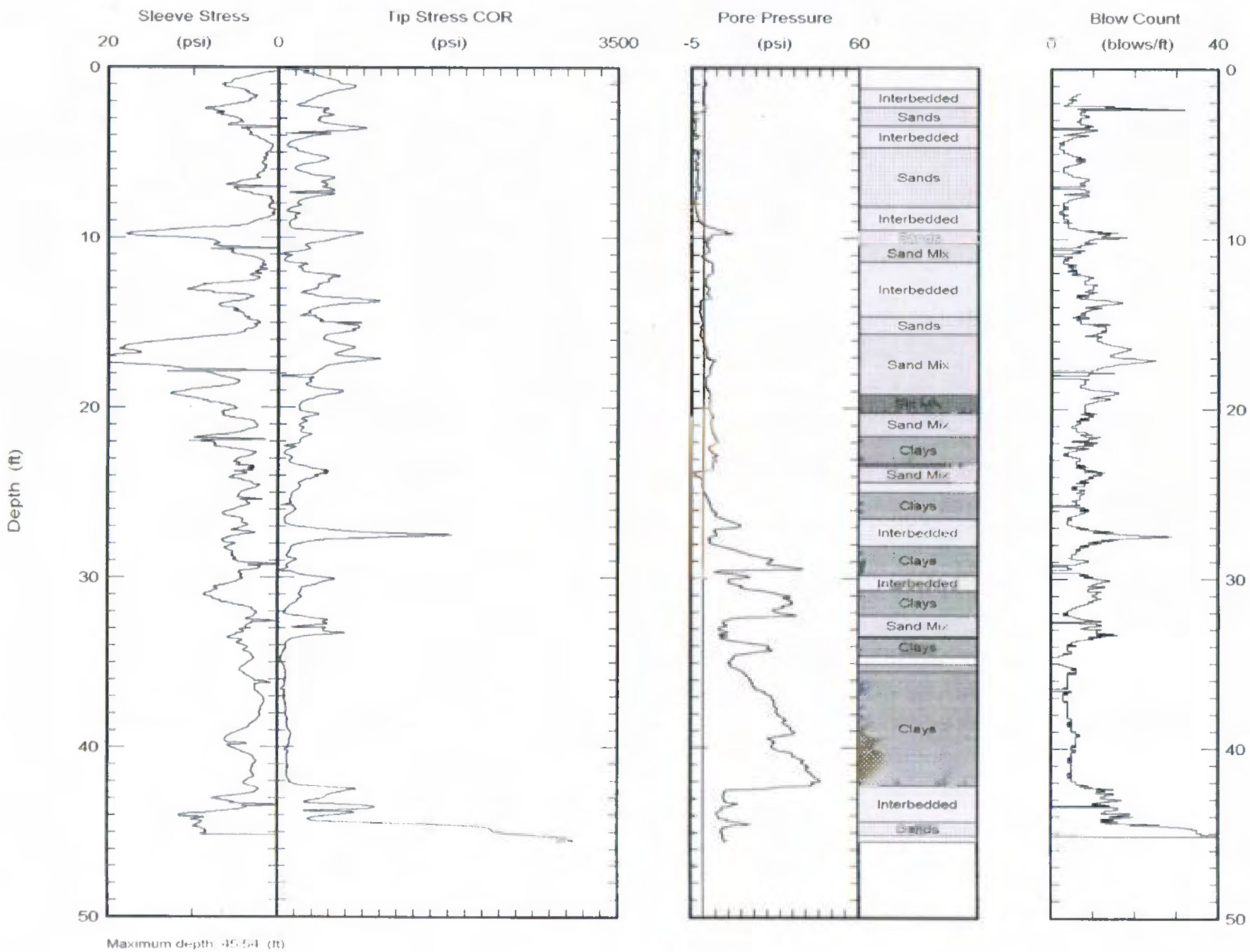
Applied Research Associates, Inc.
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com

Northing:	Date: 09/May/2011
Easting:	Test ID: cpt1
Elevation:	Project: Alliant
Client: Aetherdbs	
Job Site: Burlington	

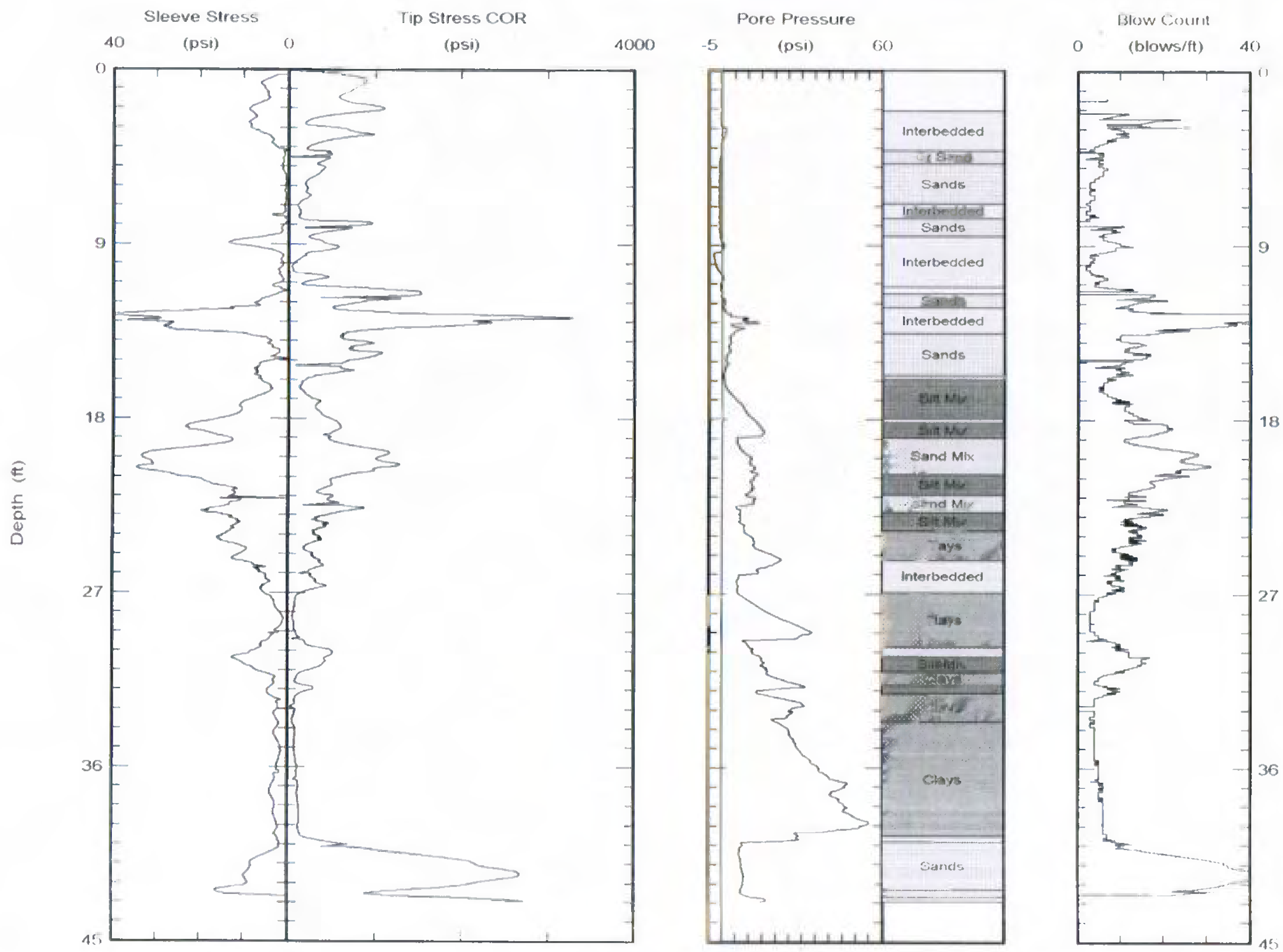


Maximum depth: 43.92 (ft)

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 09/May/2011 Test ID: cpt2 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



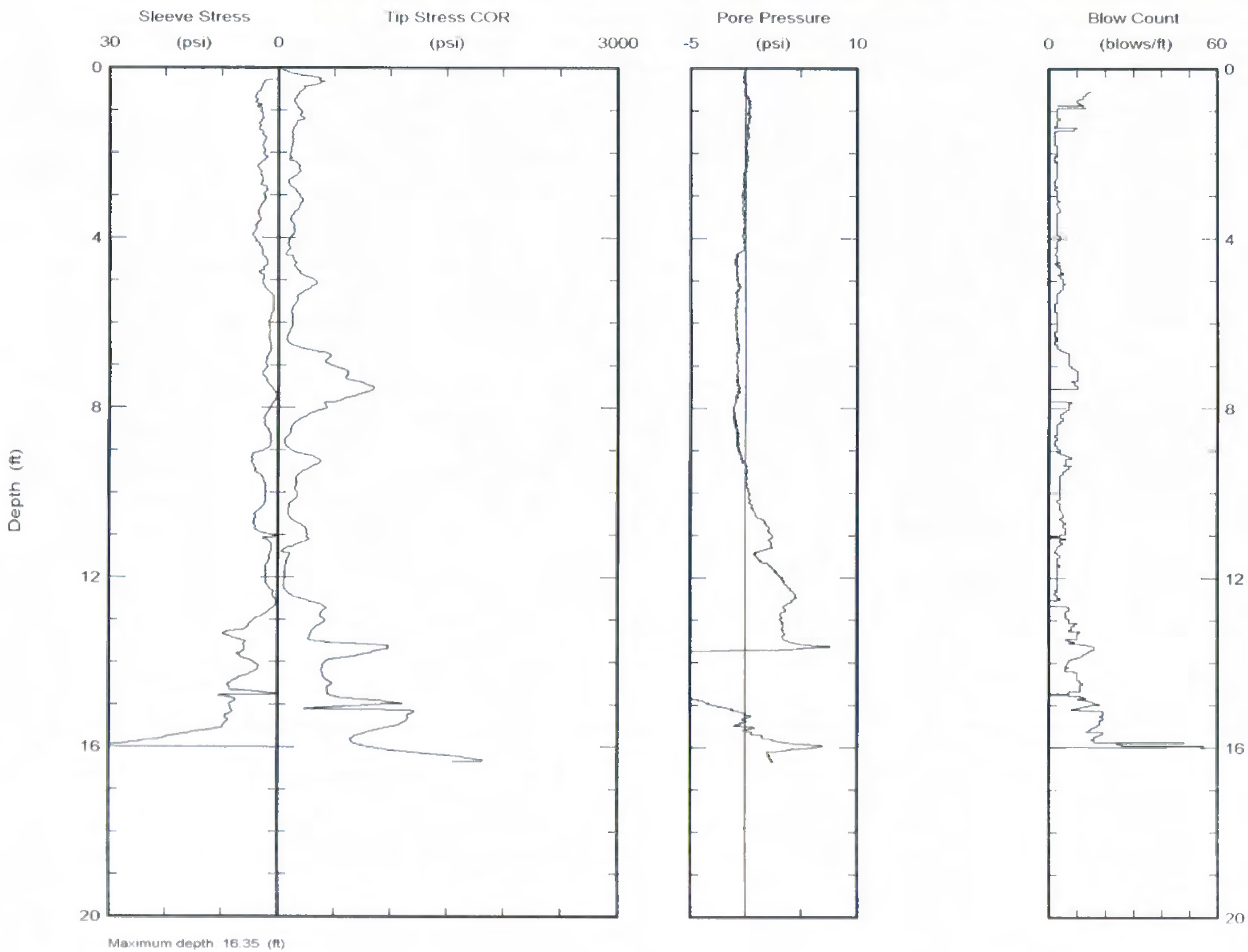
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 09/May/2011 Test ID: cpt3 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



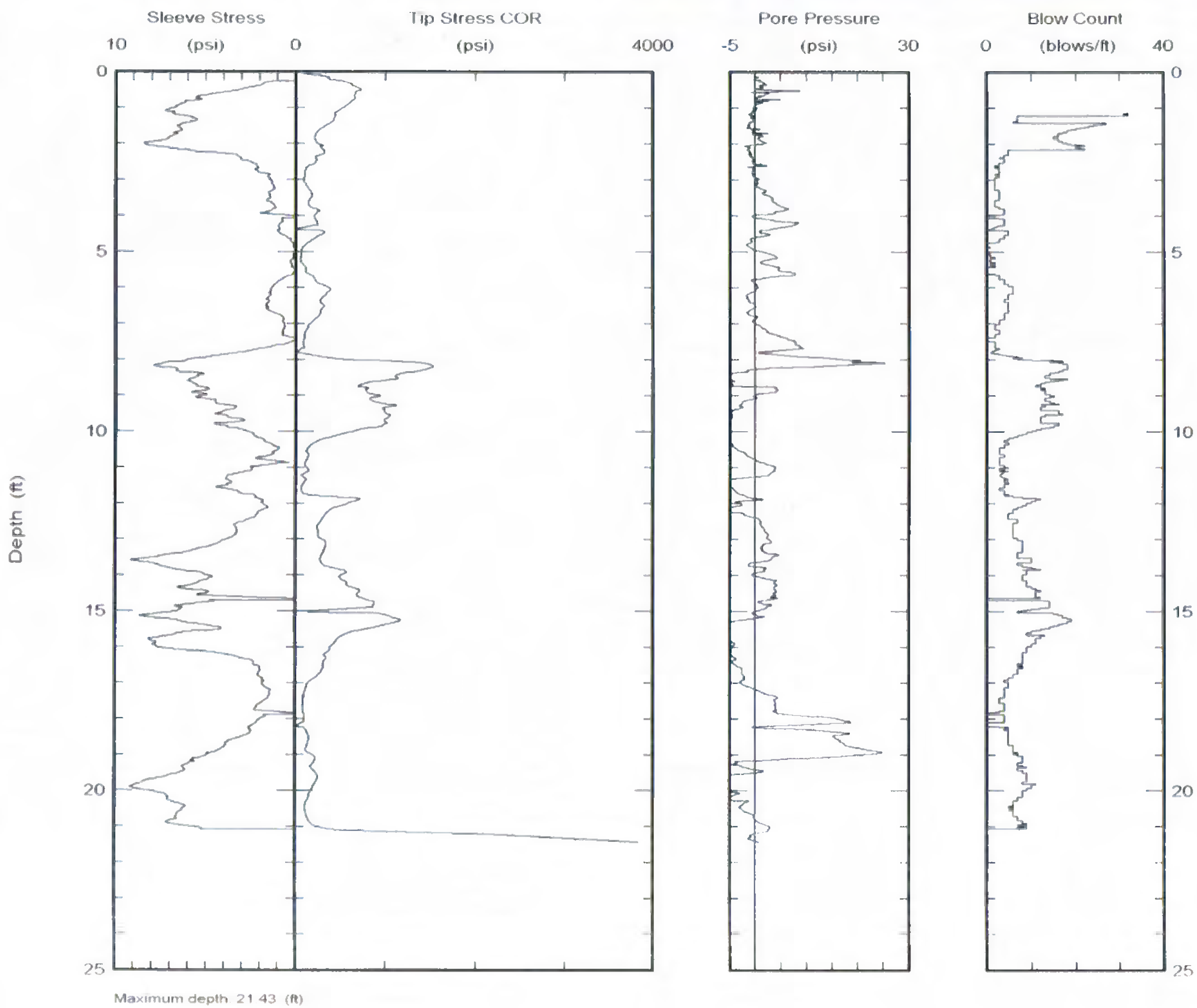
Maximum depth: 42.94 (ft)

Applied Research Associates, Inc.
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com

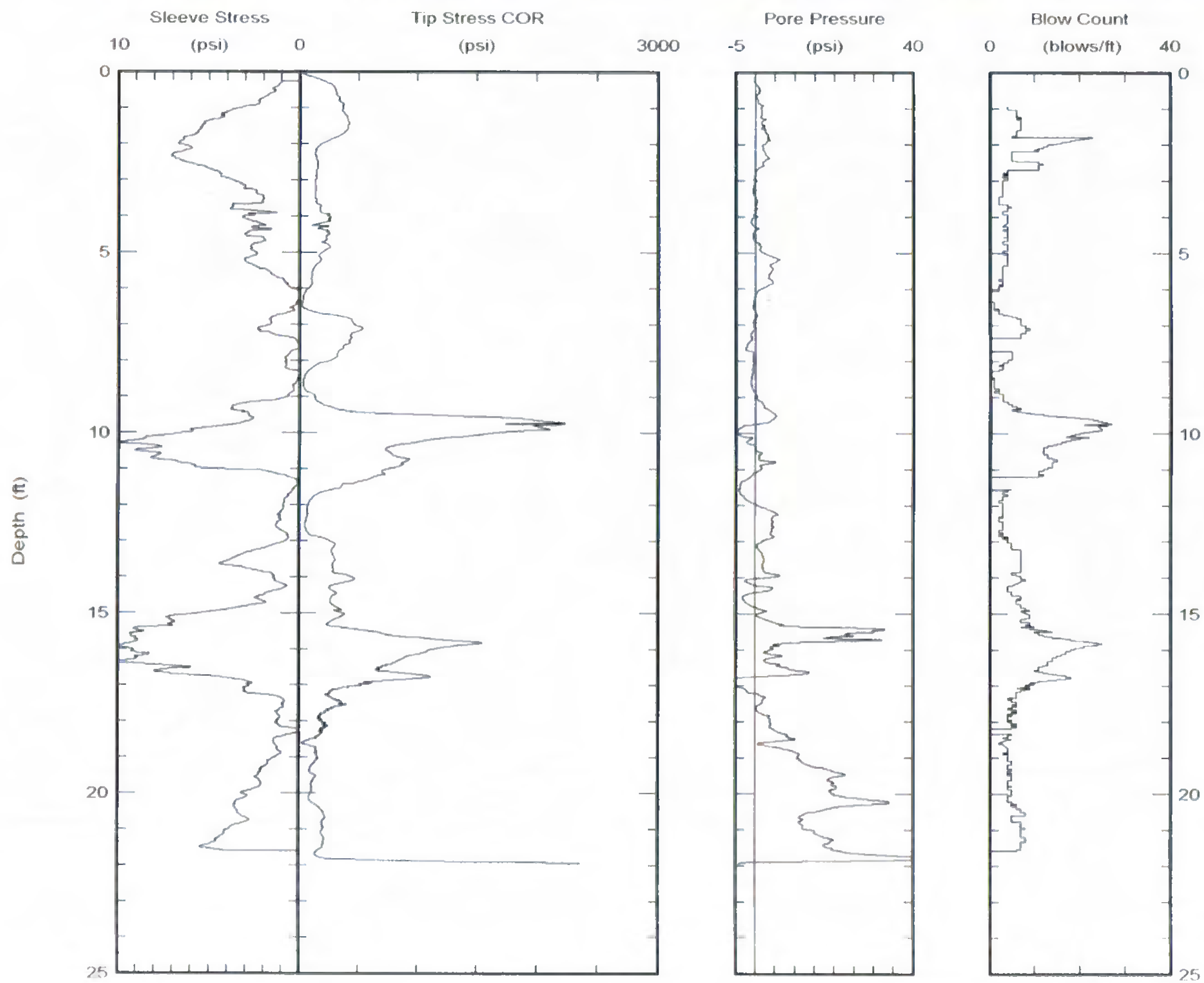
Northing:	Date: 09/May/2011
Easting:	Test ID: cpt4
Elevation:	Project: Alliant
Client: Aetherdbs	
Job Site: Burlington	



Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt5 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



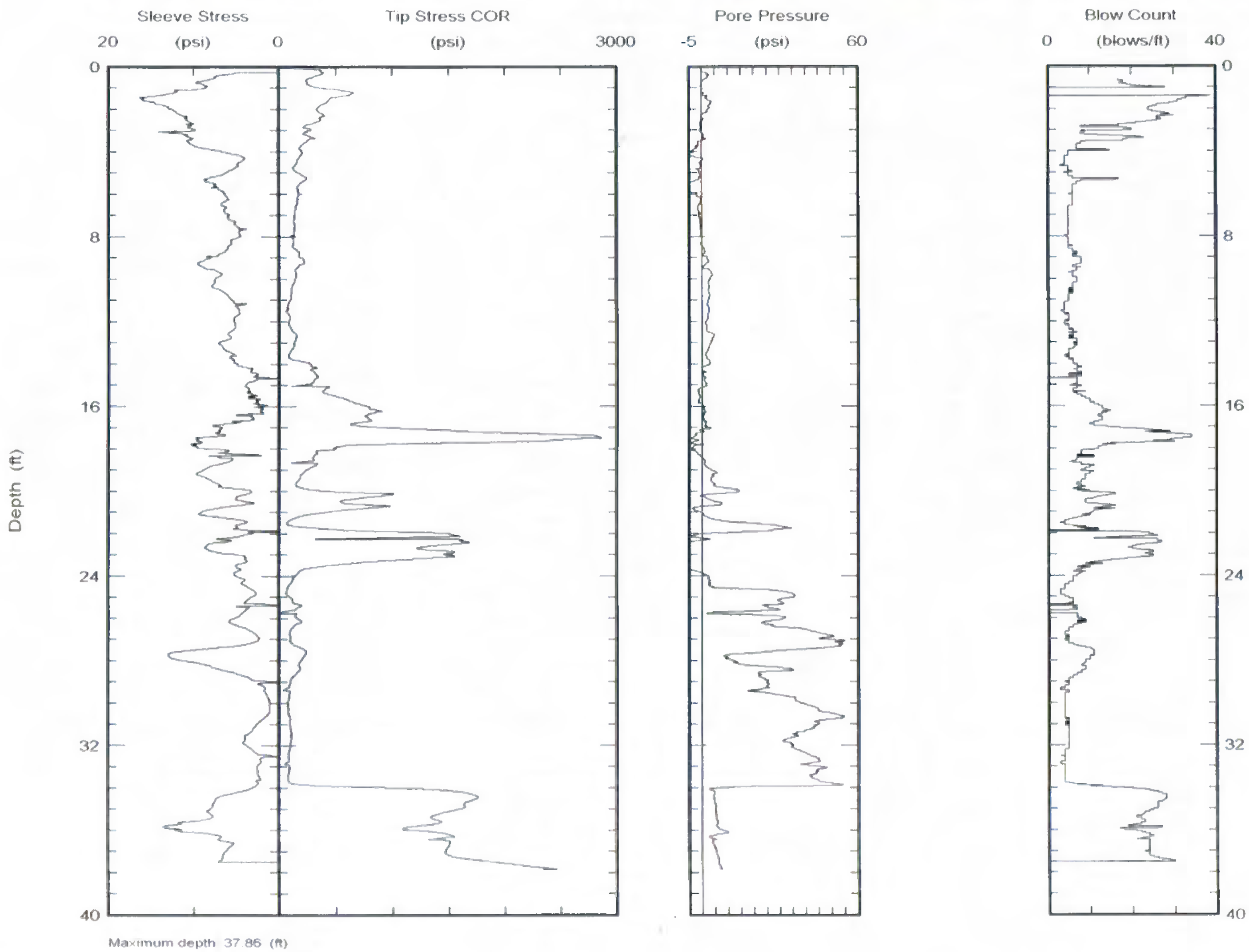
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt6 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



Maximum depth: 21.96 (ft)

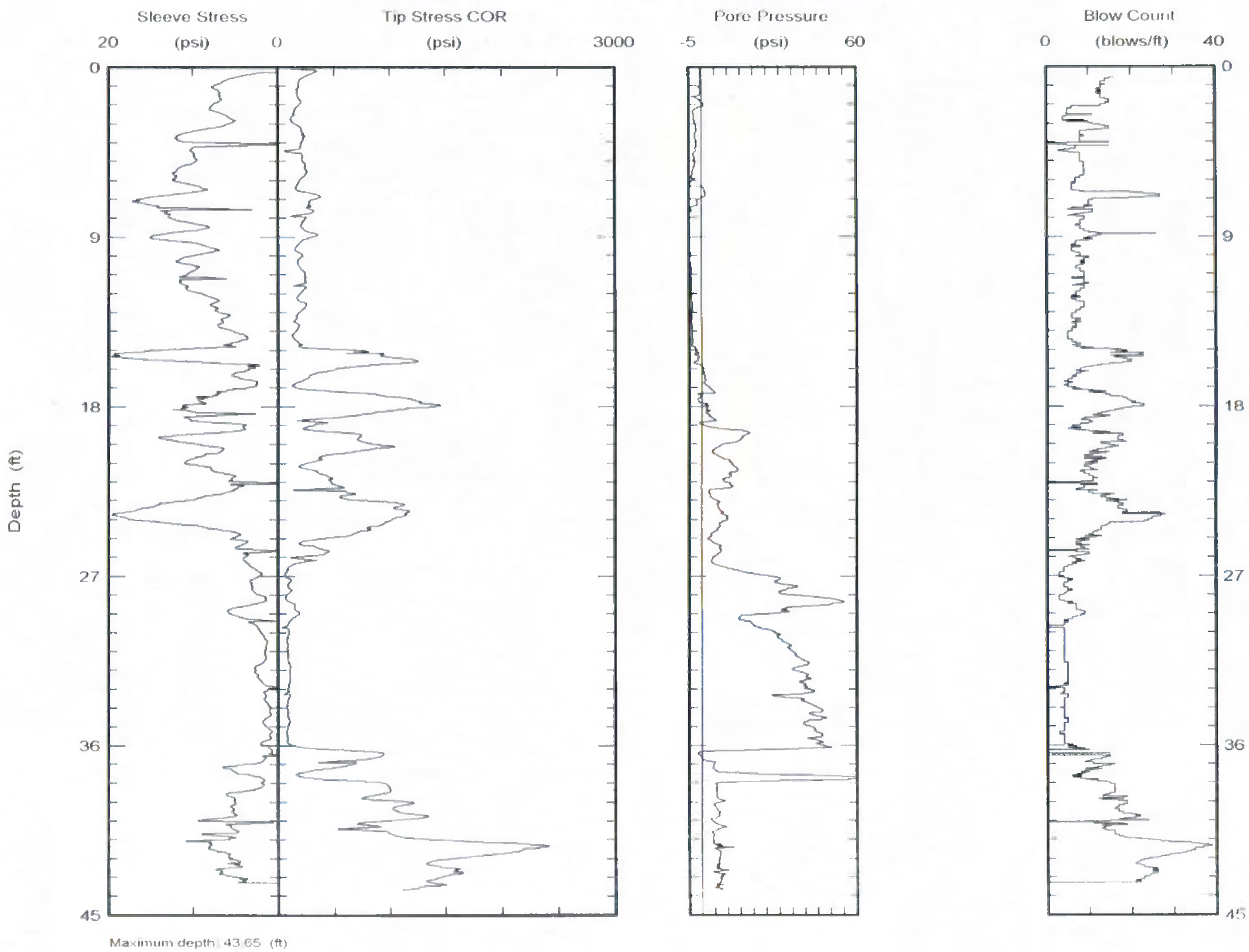
Test ID: cpt6

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt7 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



11/25/2020 - Classification: Internal - ECRM7803923

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt8 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

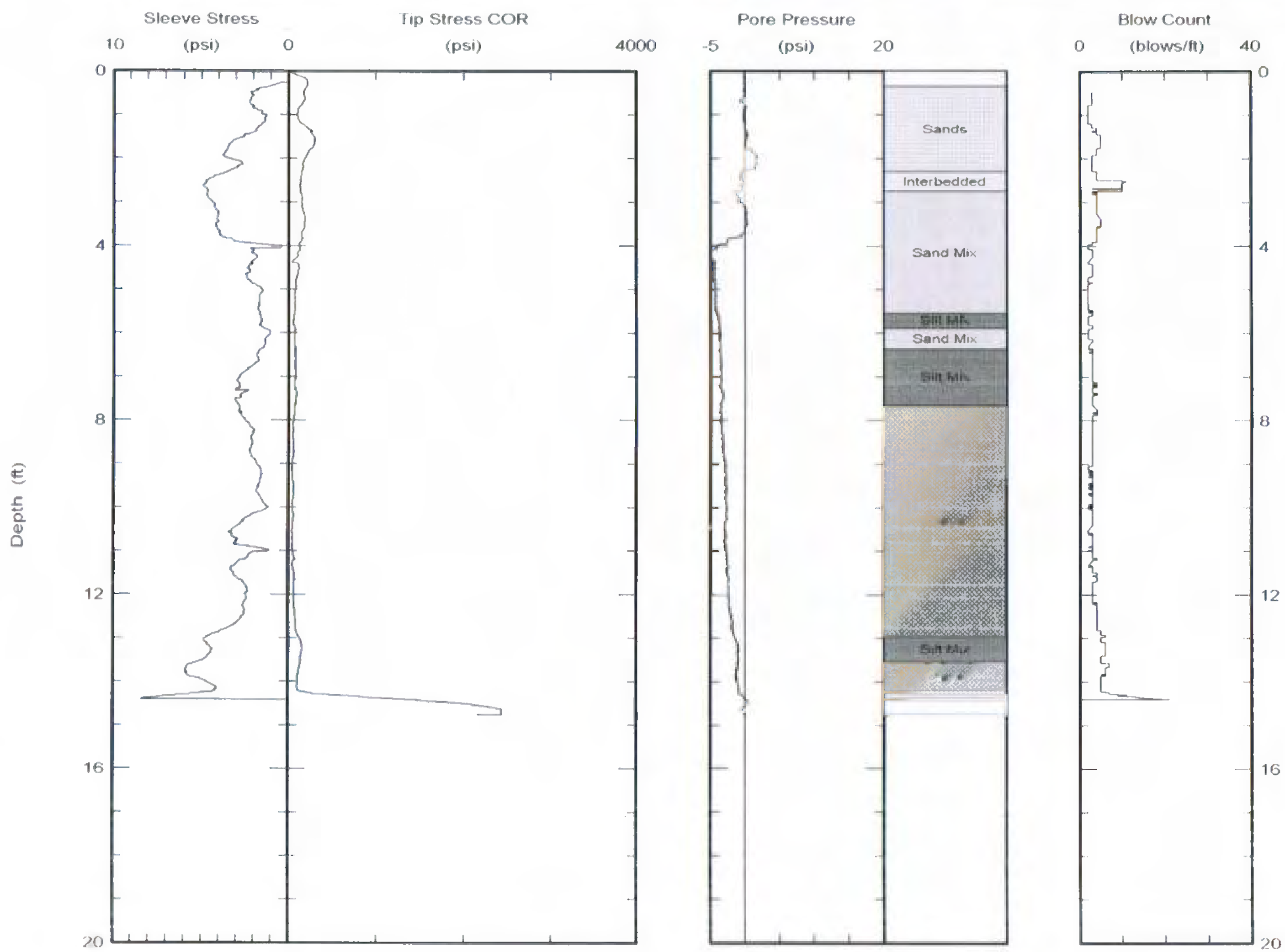


11/25/2020 - Classification: Internal - ECRM7803923

Applied Research Associates, Inc.
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com

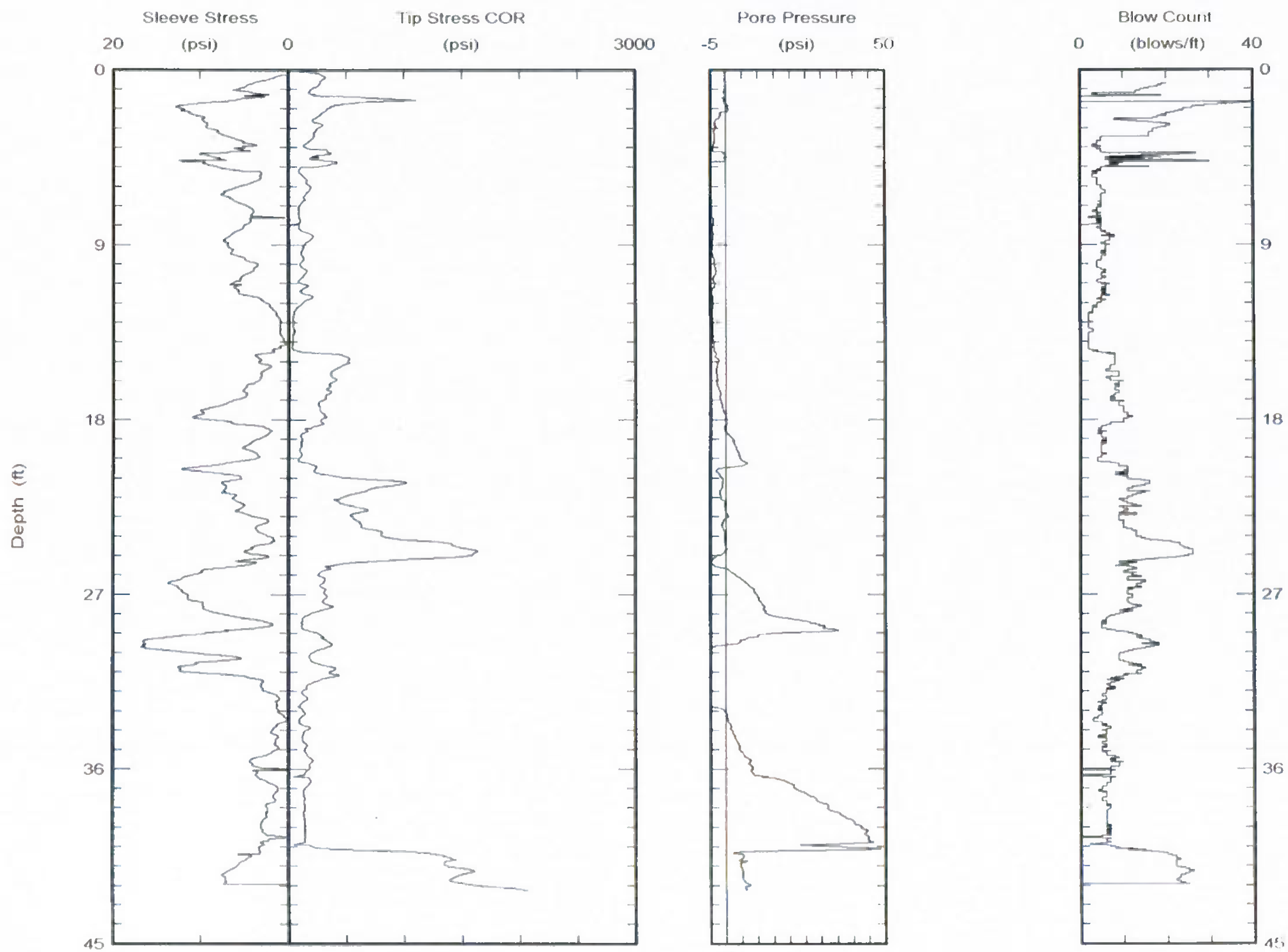
Northing:
Easting:
Elevation:
Client: Aetherdbs
Job Site: Burlington

Date: 10/May/2011
Test ID: cpt9
Project: Alliant



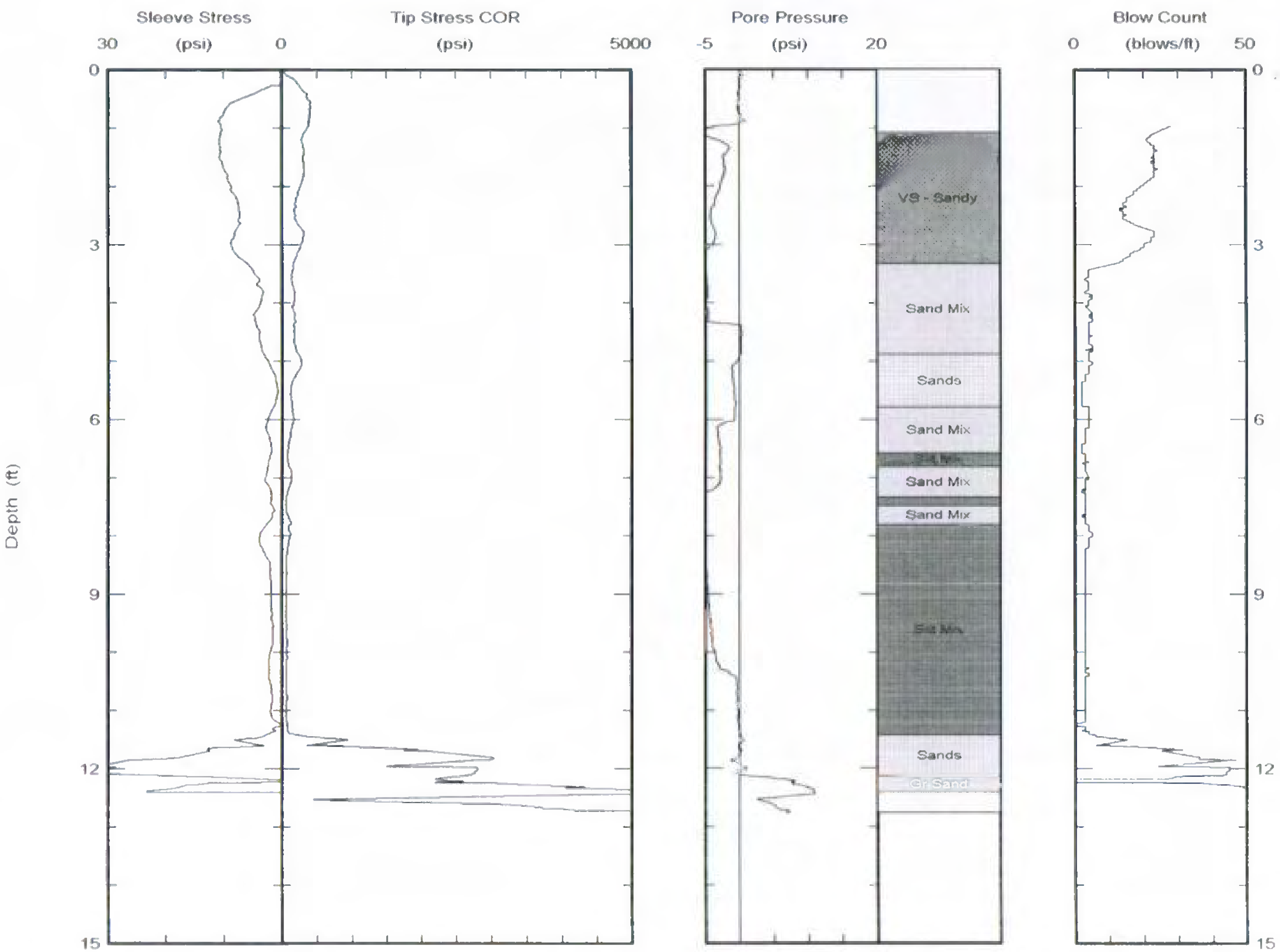
Maximum depth 14.76 (ft)

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt10 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



Maximum depth: 42.27 (ft)

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt11 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

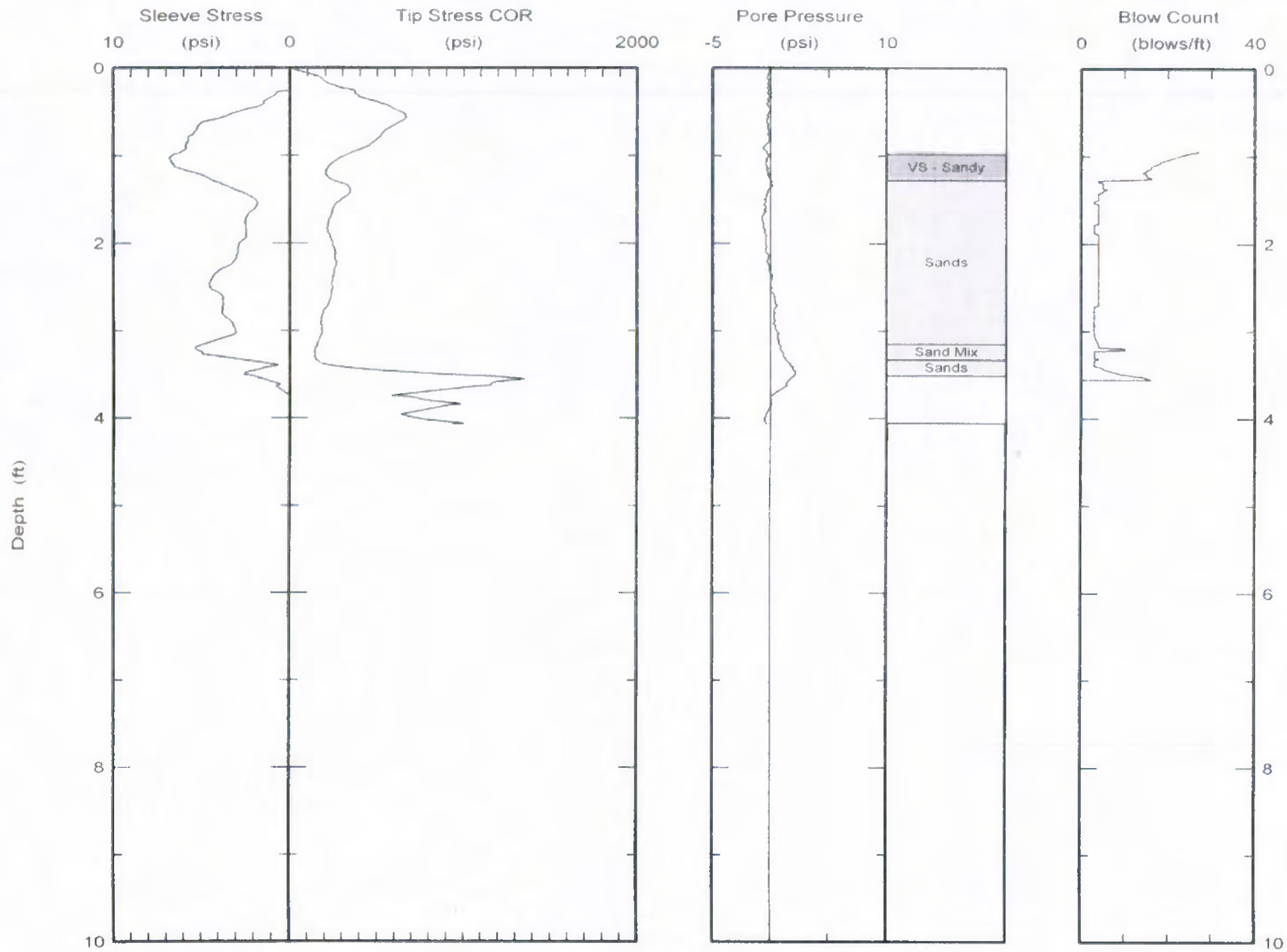


Maximum depth: 12.76 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

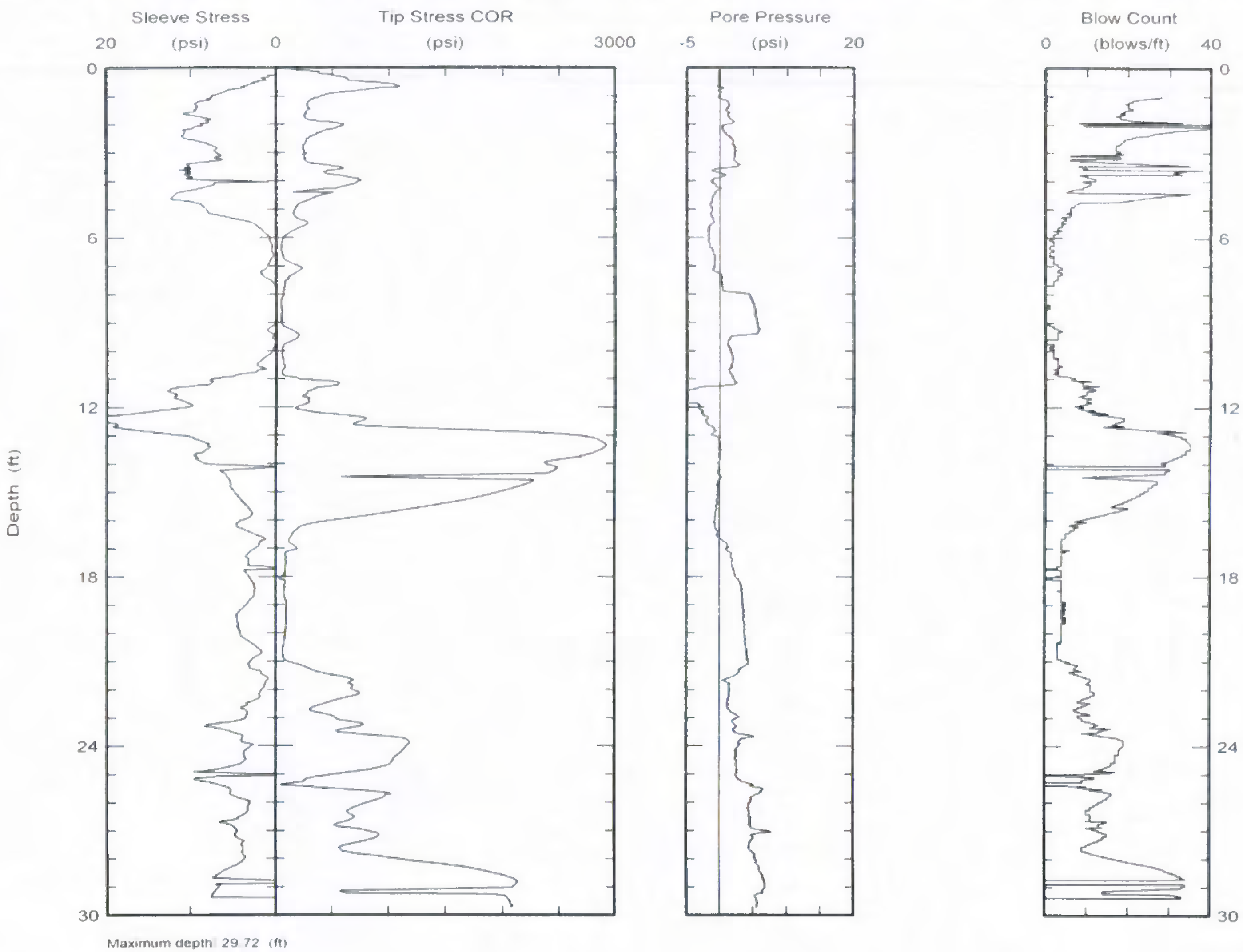
Test ID cpt11
File A10Y1107C ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt12 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



Maximum depth: 4.06 (ft)

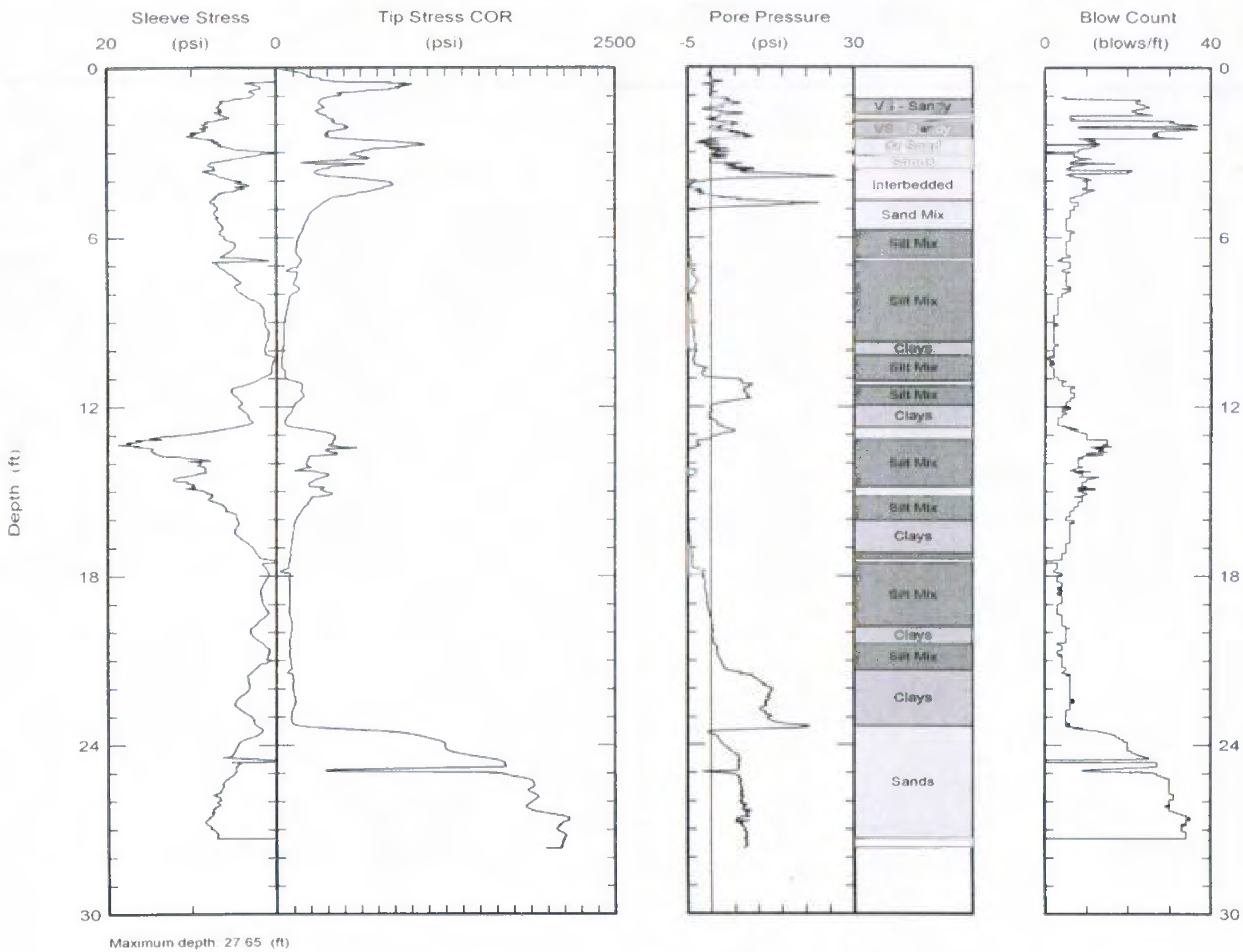
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt13 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt13
File: A10Y1109C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 15/May/2011 Test ID: cpt14 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

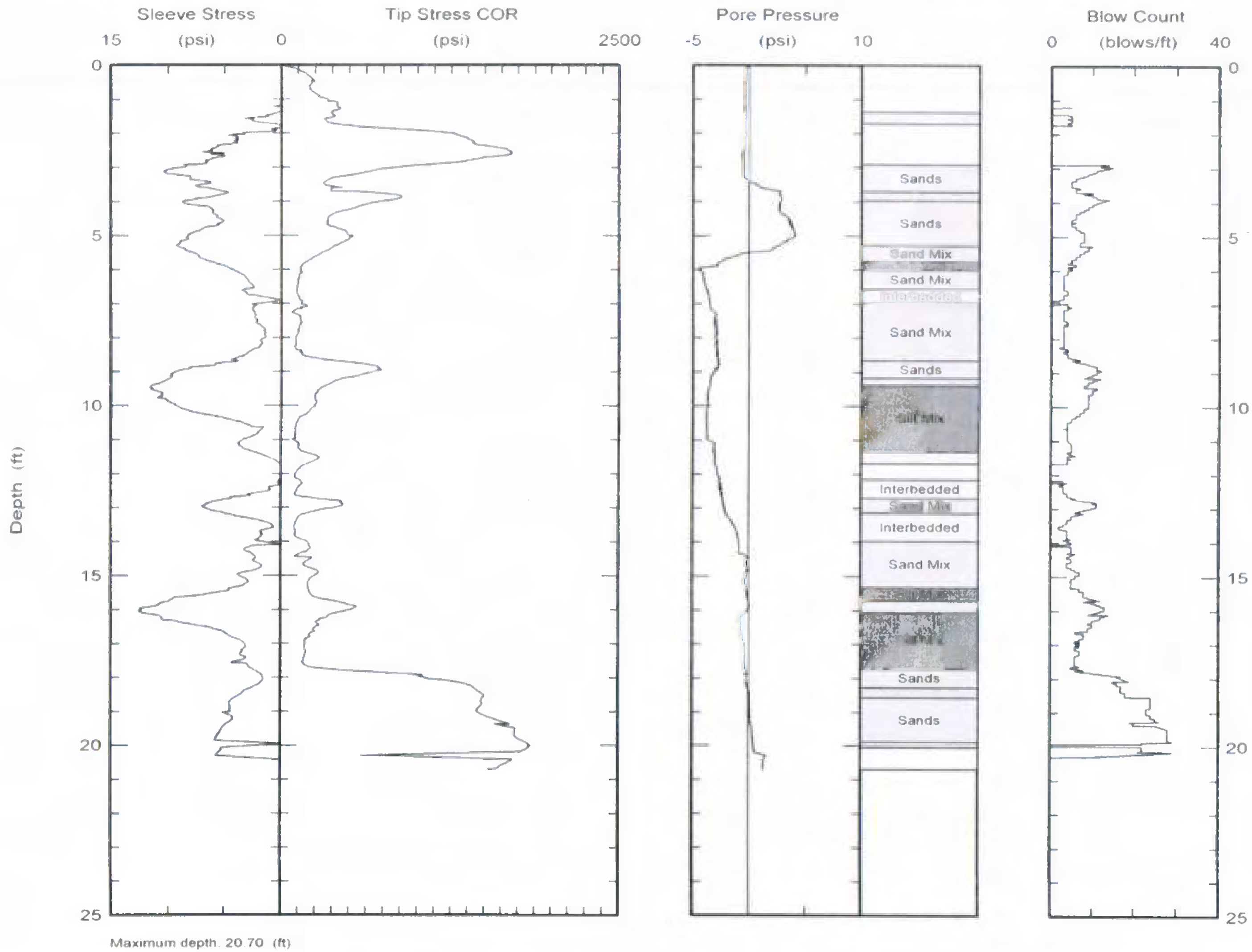


Maximum depth: 27.65 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

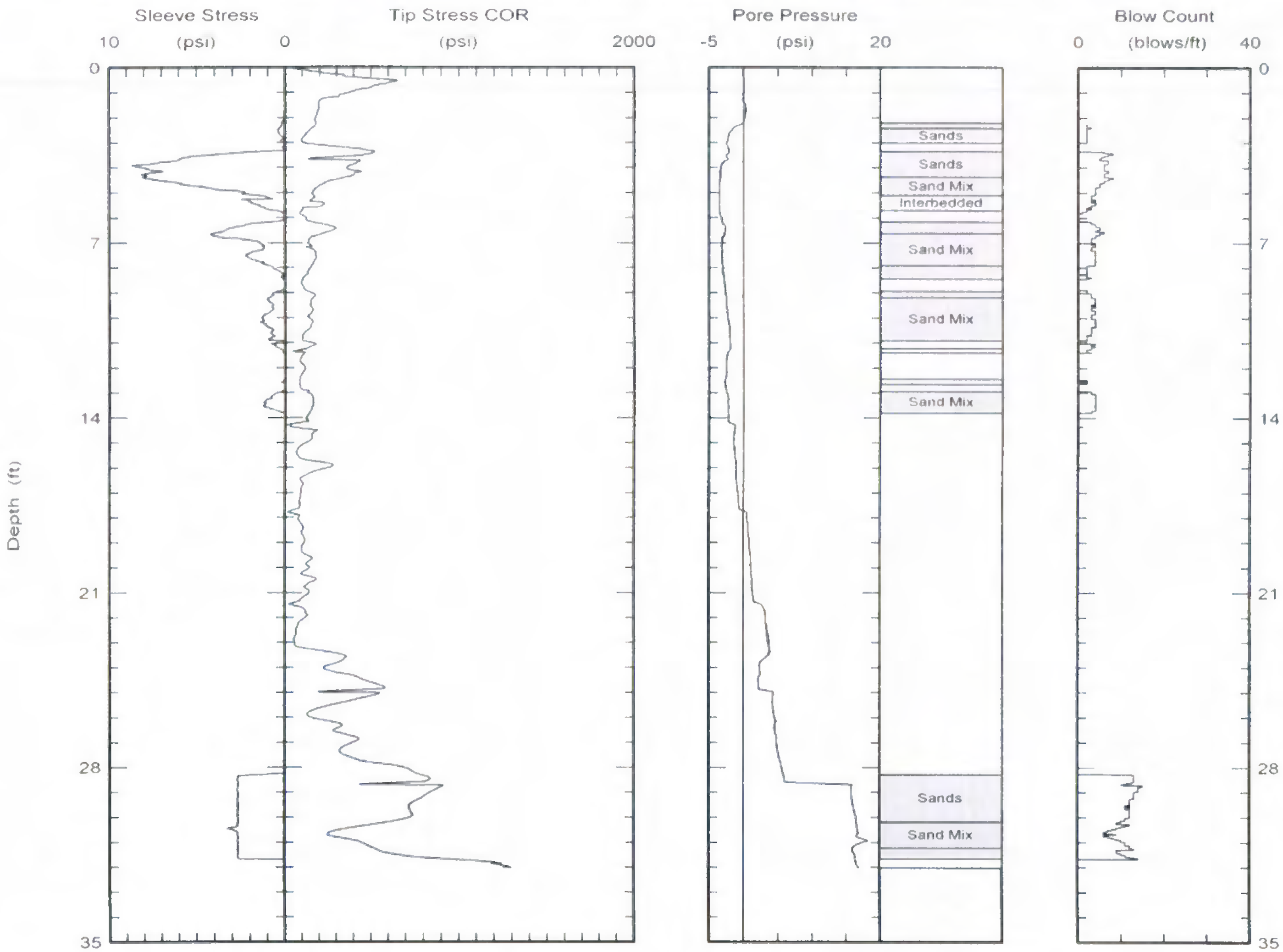
Test ID: cpt14
File: A15Y1101C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 15/May/2011 Test ID: cpt15 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



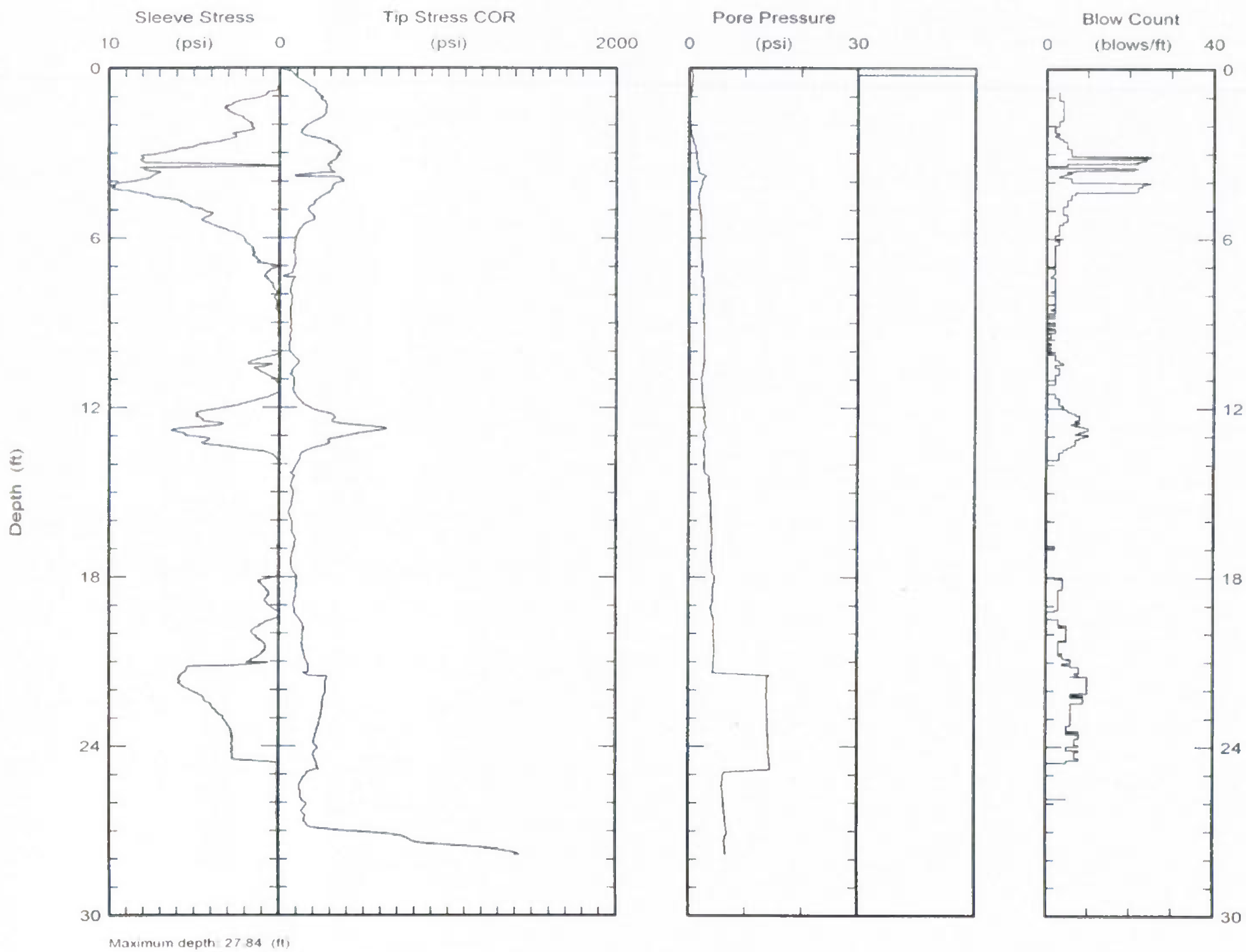
11/25/2020 - Classification: Internal - ECRM7803923

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 15/May/2011 Test ID: cpt16 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



Maximum depth: 32.02 (ft)

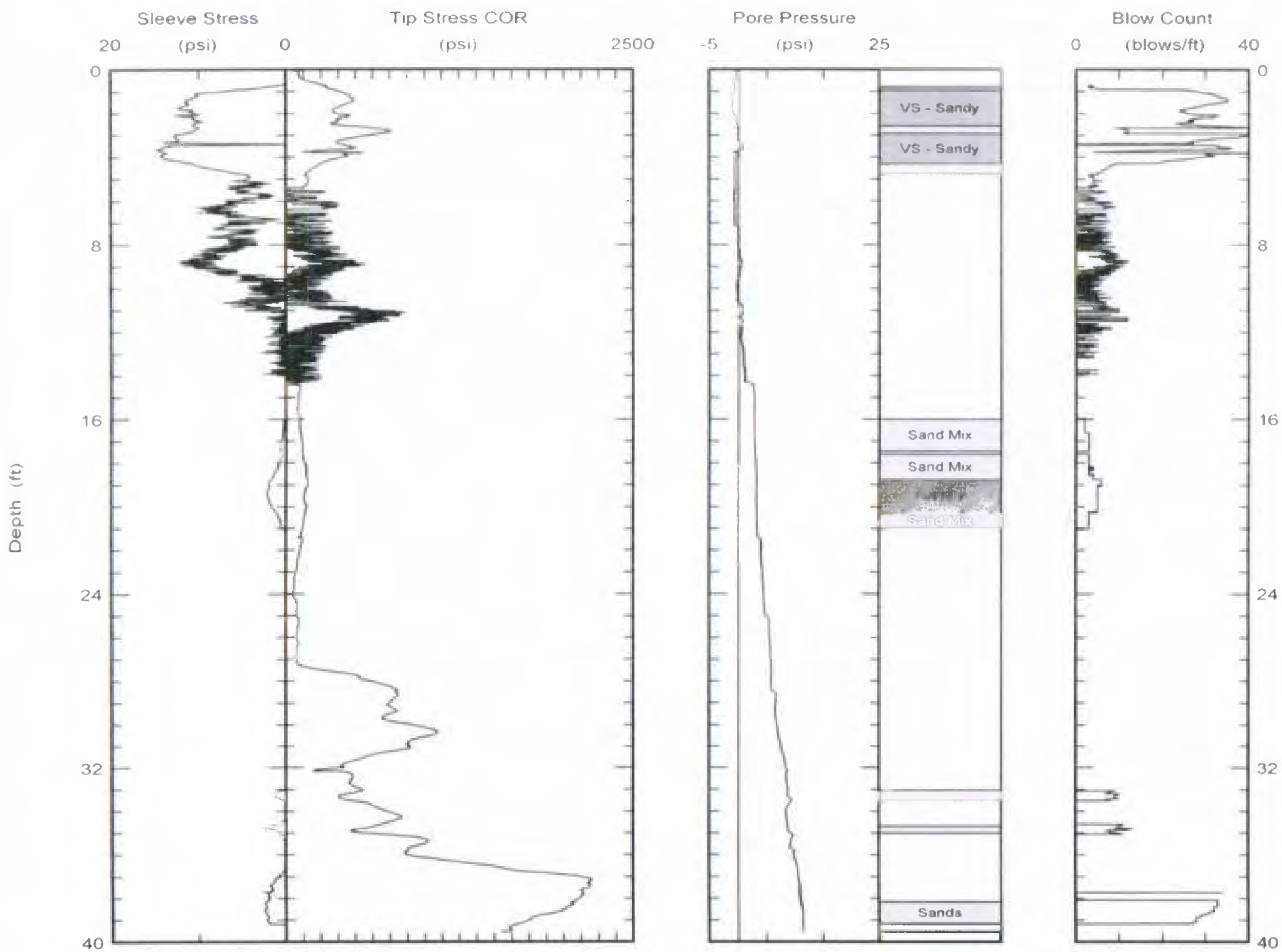
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 15/May/2011 Test ID: cpt17 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt17

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 15/May/2011 Test ID: cpt18 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

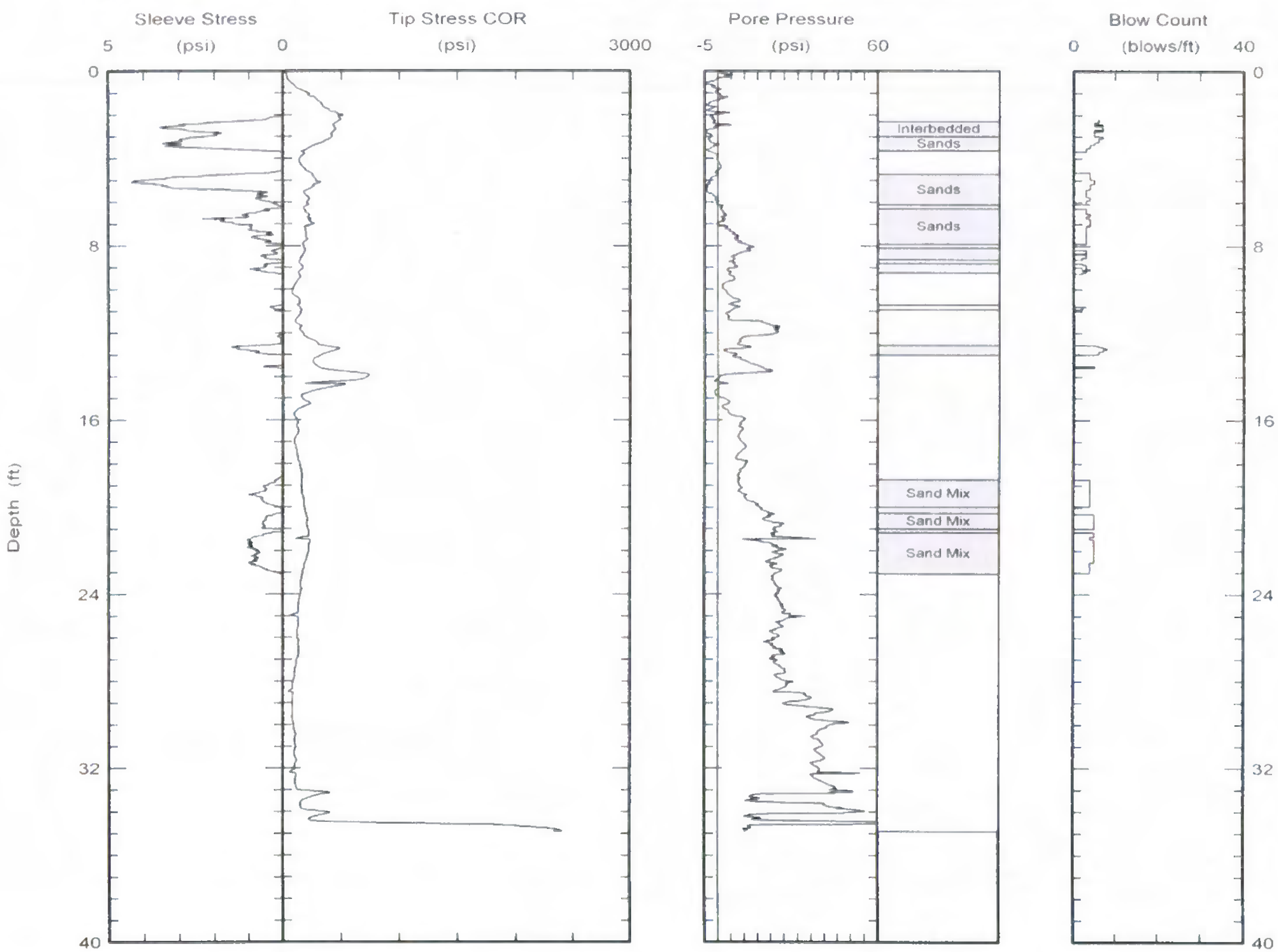


Maximum depth: 39.53 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt18
File: A15Y1105C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 16/May/2011 Test ID: cpt19 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

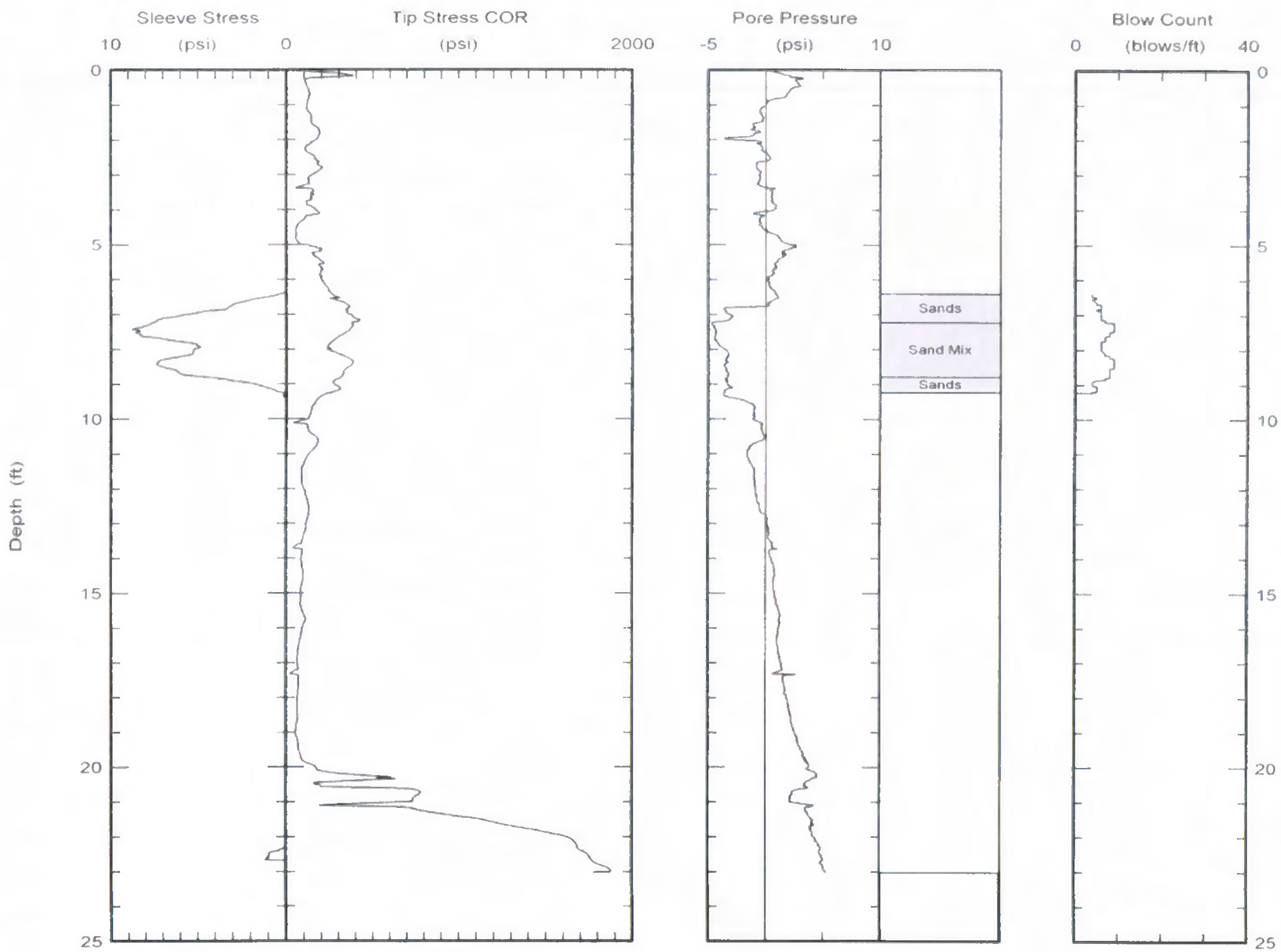


Maximum depth: 34.90 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt19
File: A16Y1101C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 16/May/2011 Test ID: cpt20 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

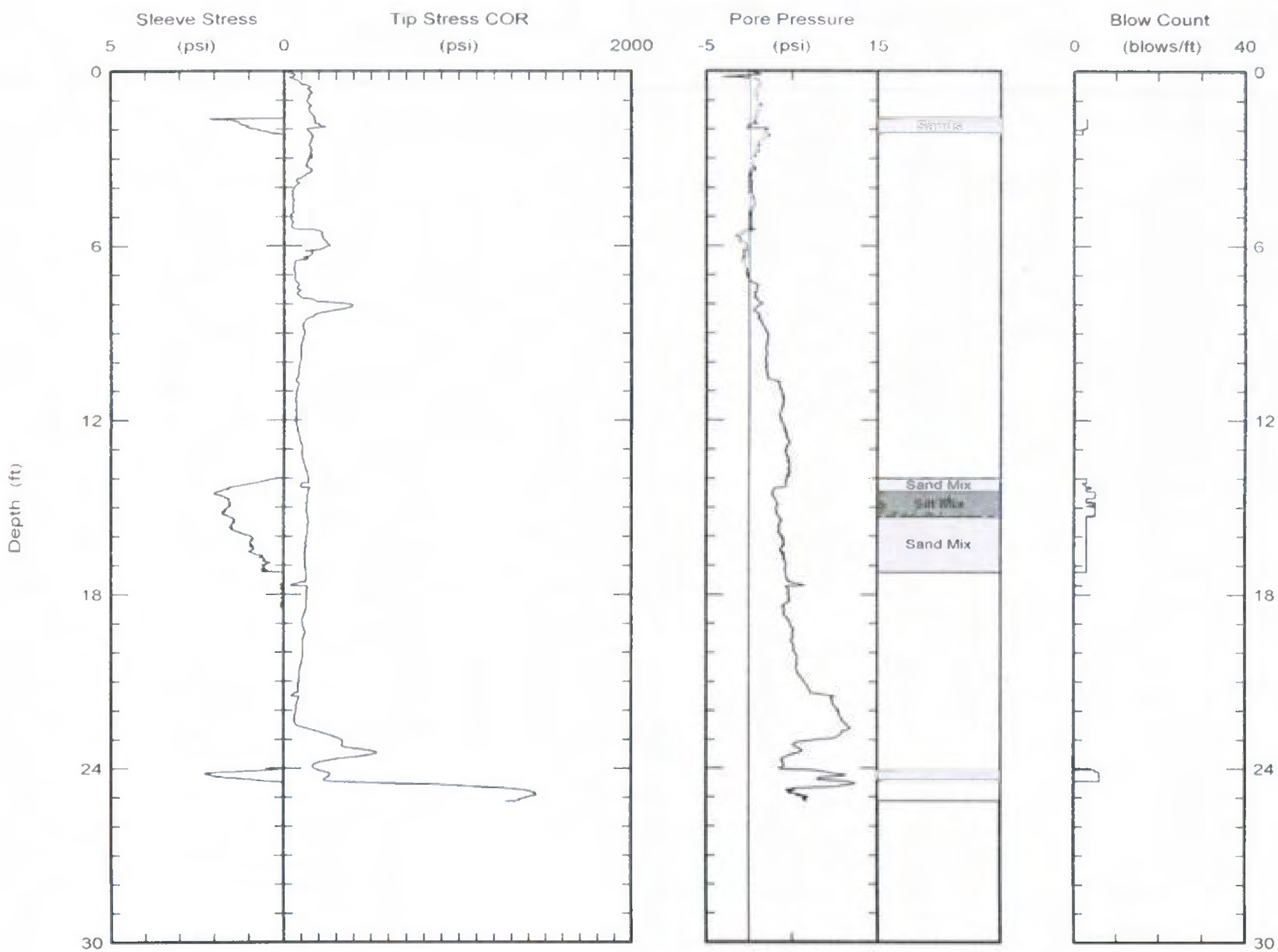


Maximum depth: 23.02 (ft)

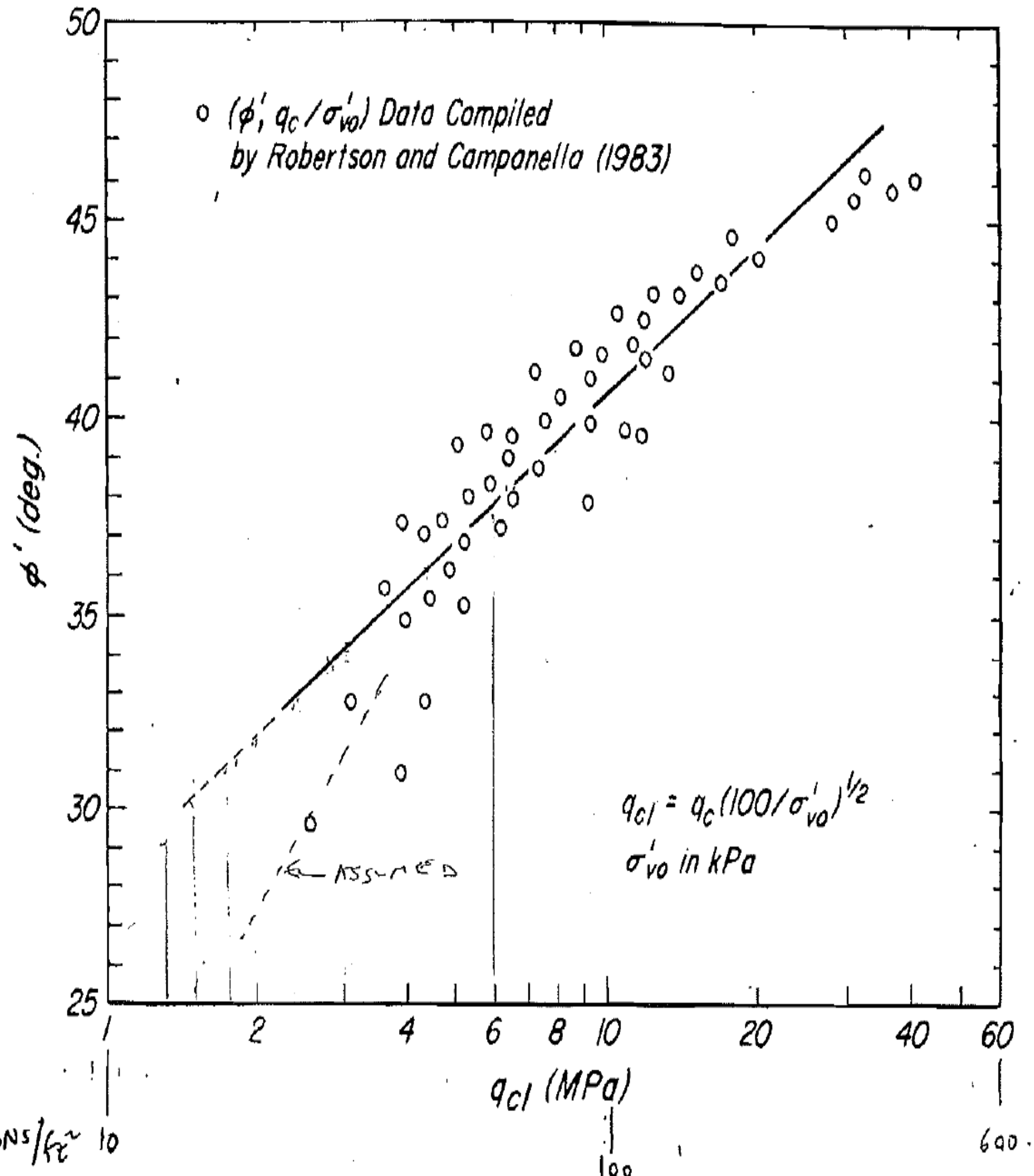
11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt20
File: A16Y1102C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 16/May/2011 Test ID: cpt21 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



Maximum depth: 25.13 (ft)



19.5 Empirical correlation between friction angle ϕ' of sands and norma penetration resistance.

Re: TERZAGHI PECK & MESRI (1996), SOIL MECHANICS IN ENG. PRACTICE, 3RD ED., JOHN WILEY & SONS, INC

APPENDIX D – Laboratory Testing on CCR Embankment Soils

Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

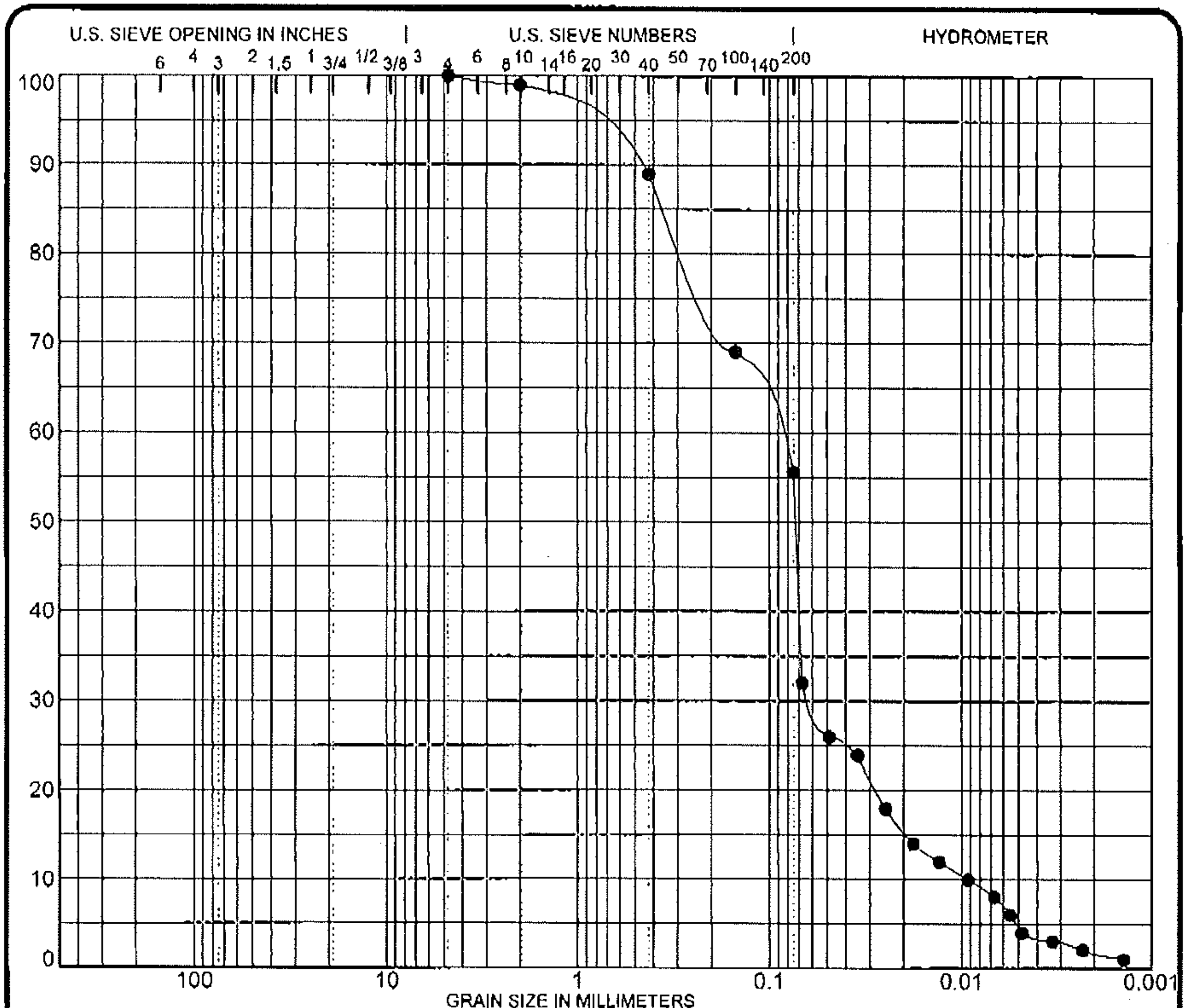
Safety Factor Assessment

Attachment C

Soil Laboratory Results

Burlington Generating Station

Source: Testing Service Corporation, May 2011



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Broing: SB-1	3 inch	100	Brown ASH			
Sample: Ash	2	100				
	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	44	54	2
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	99	44.0	NP	NP	NP
	# 40	89				
	# 100	69				
	# 200	56				

PROJECT Geotechnical Testing
LOCATION ,

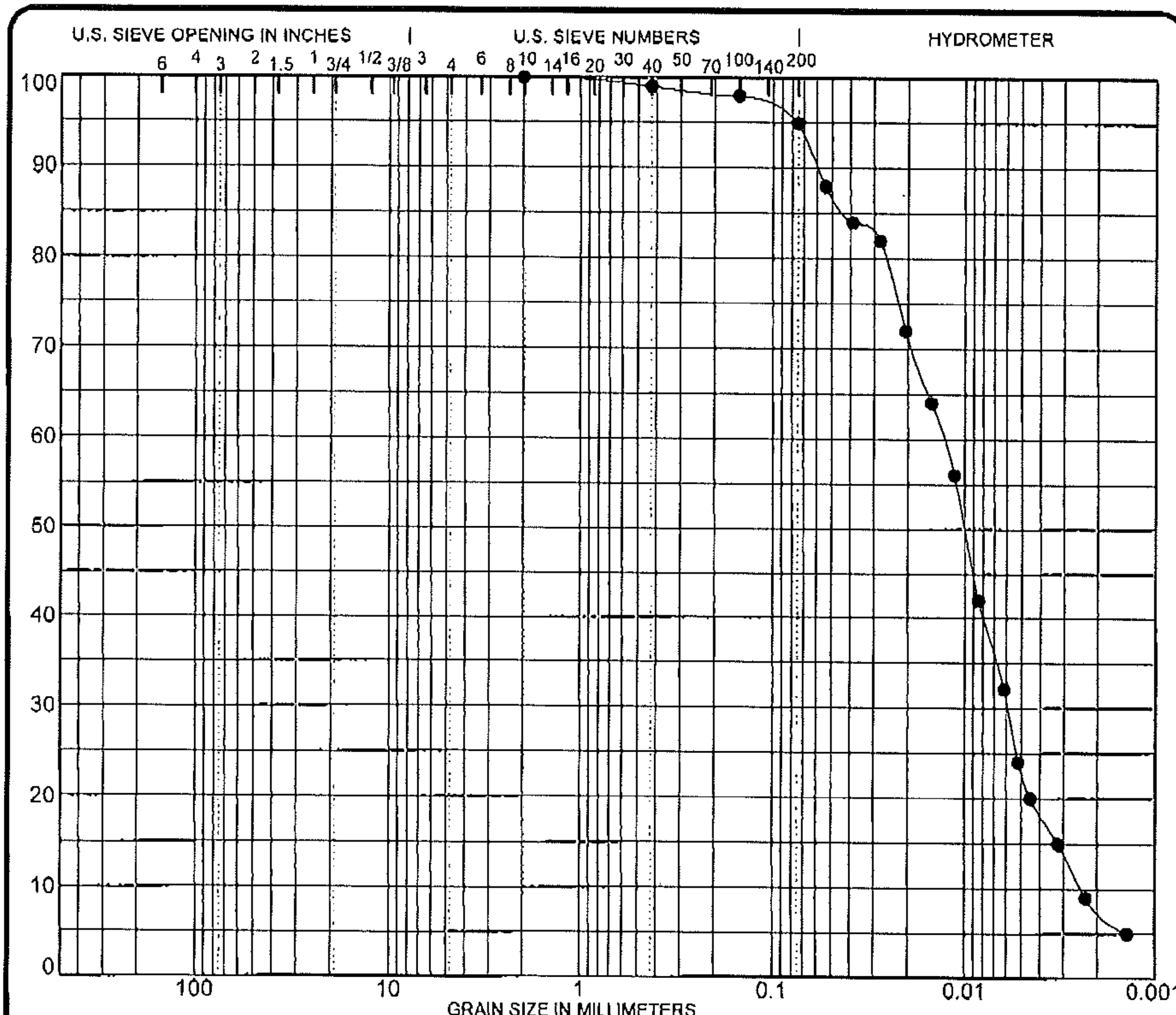
JOB NO. L - 76,757
DATE May 20, 2011

SB1

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/20/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS
Boring: SB-1	3 inch	100
Sample: A	2	100
Depth: 25.0'-26.0'	1 1/2	100
	1	100
NOTES:	3/4	100
	3/8	100
	# 4	100
	# 10	100
	# 40	99
	# 100	98
	# 200	95

SOIL CLASSIFICATION

Gray clayey SILT, trace sand (ML)

%GRAVEL	%SAND	%SILT	%CLAY
0	5	87	8

MC%		LL	PL	PI
69.4		36	31	5

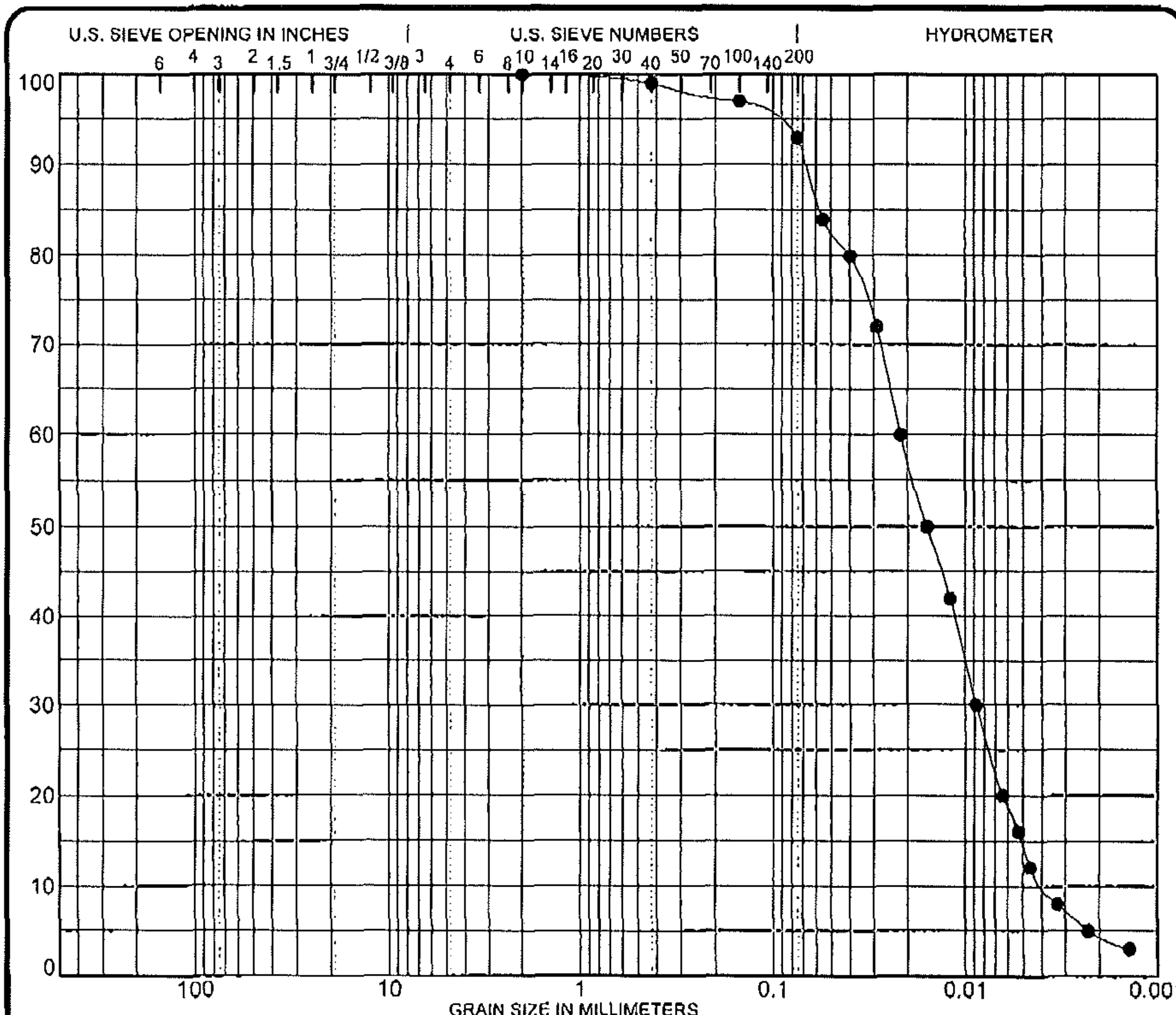
PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 20, 2011

SB1

SOIL DATA SHEET
Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/20/11

05/20/2011 11:48 FAX



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-1	3 inch	100	Gray clayey SILT, trace sand (ML)
Sample: 8	2	100	
Depth: 29.0'-30.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	100	
	# 4	100	
	# 10	100	
	# 40	99	
	# 100	97	
	# 200	93	

%GRAVEL	%SAND	%SILT	%CLAY
0	7	89	4

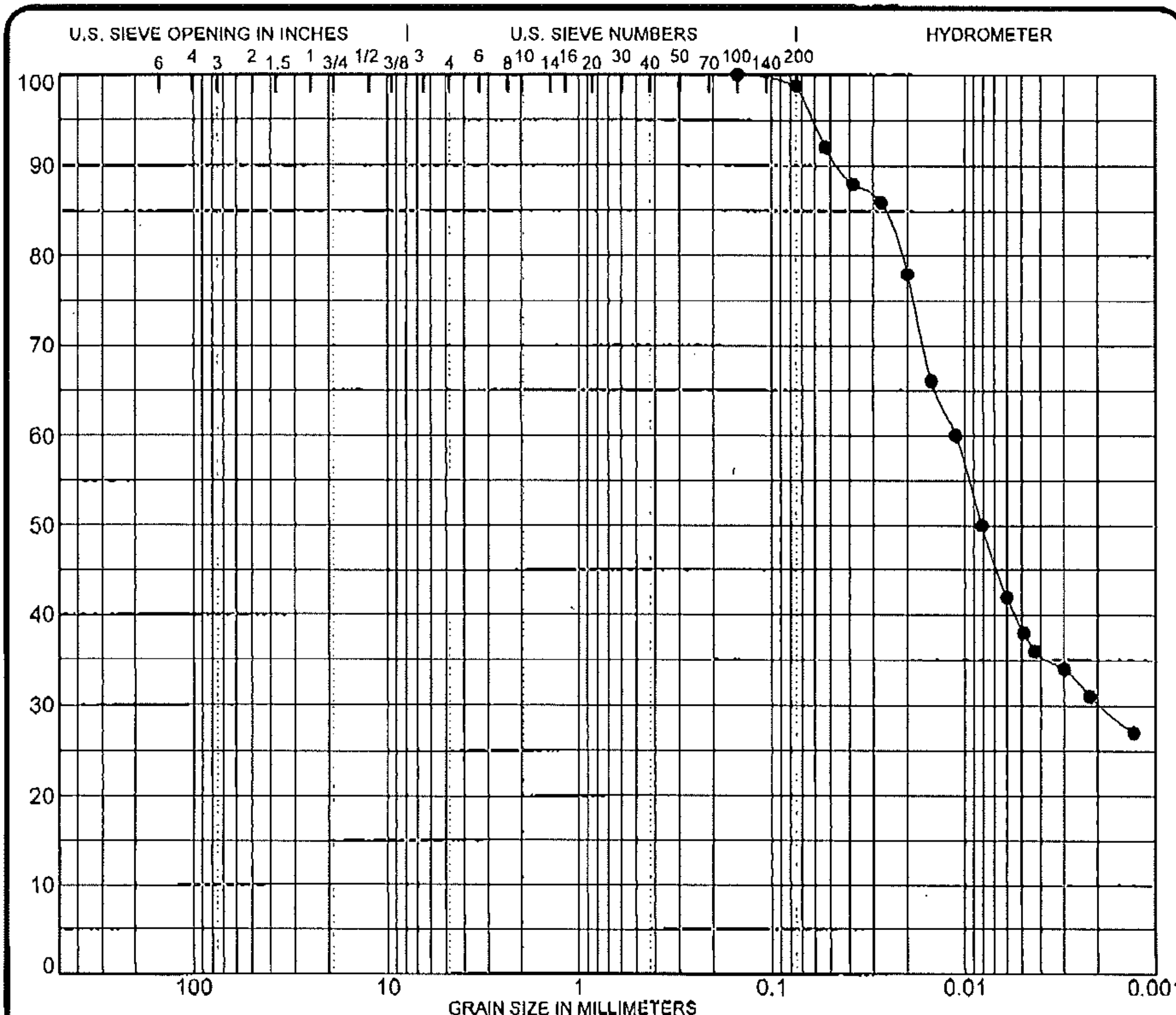
MC%		LL	PL	PI
58.6		40	37	3

PROJECT Geotechnical Testing
LOCATION ,
SB1

JOB NO. L - 76,757
DATE May 20, 2011

SOIL DATA SHEET
Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC ALL.GDT 5/20/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-1	3 inch	100	Gray silty CLAY, trace sand (CH)
Sample: C	2	100	
Depth: 34.0'-35.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	100	
	# 4	100	
	# 10	100	
	# 40	100	
	# 100	100	
	# 200	99	

%GRAVEL	%SAND	%SILT	%CLAY
0	1	69	30

MC%		LL	PL	PI
31.3		52	17	35

PROJECT Geotechnical Testing
LOCATION ,
SB1

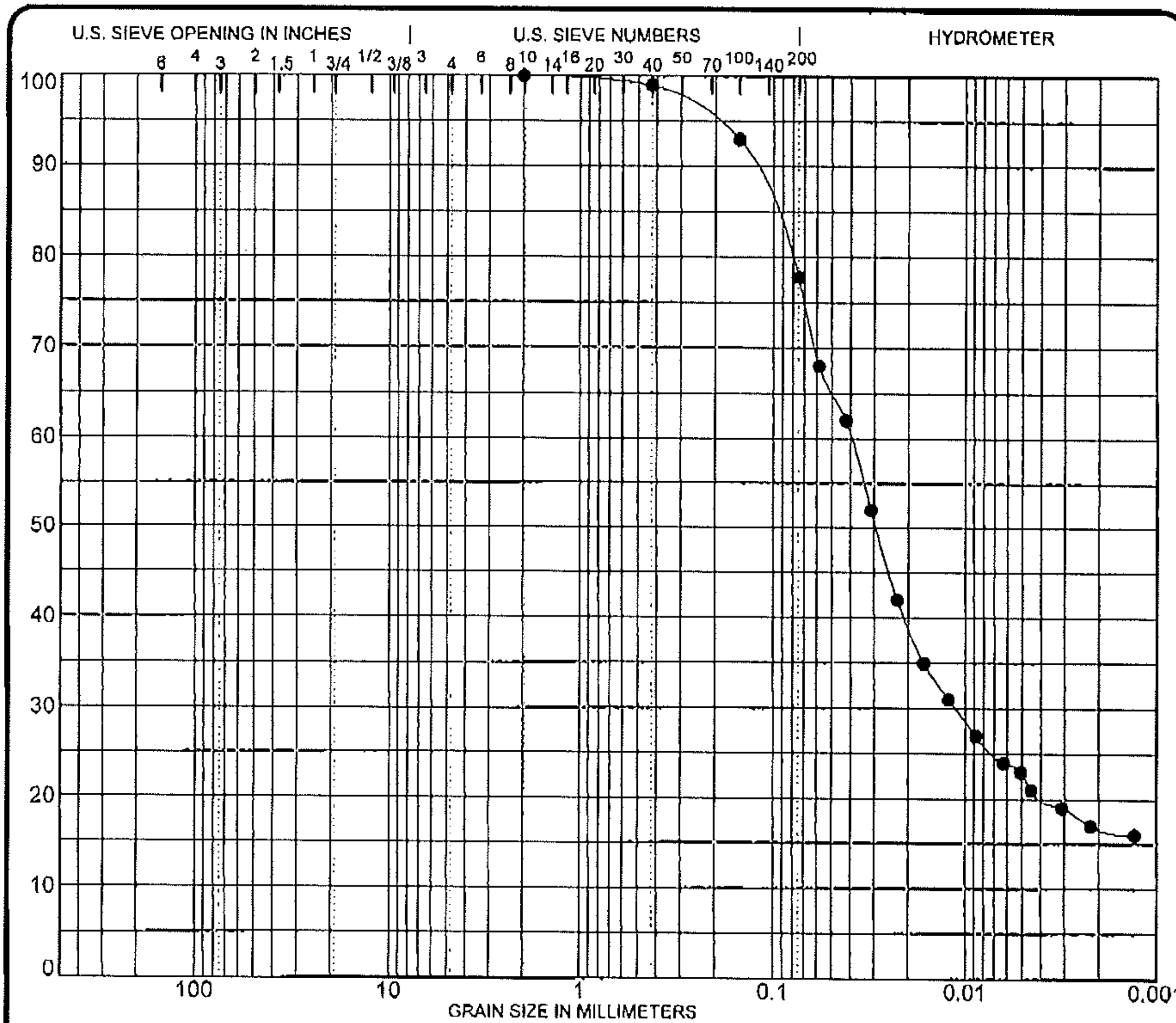
JOB NO. L - 76,757
DATE May 20, 2011

SOILGENR 76757.GPJ TSC_ALL.GDT 5/20/11

SOIL DATA SHEET

Testing Service Corporation

Carol Stream, IL 60188



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-1	3 inch	100	Gray very silty CLAY, some sand (CL)			
Sample: D	2	100				
Depth: 36.0'-37.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	22	61	17
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	100	29.1	36	16	20
	# 40	99				
	# 100	93				
	# 200	78				

PROJECT Geotechnical Testing
LOCATION ,

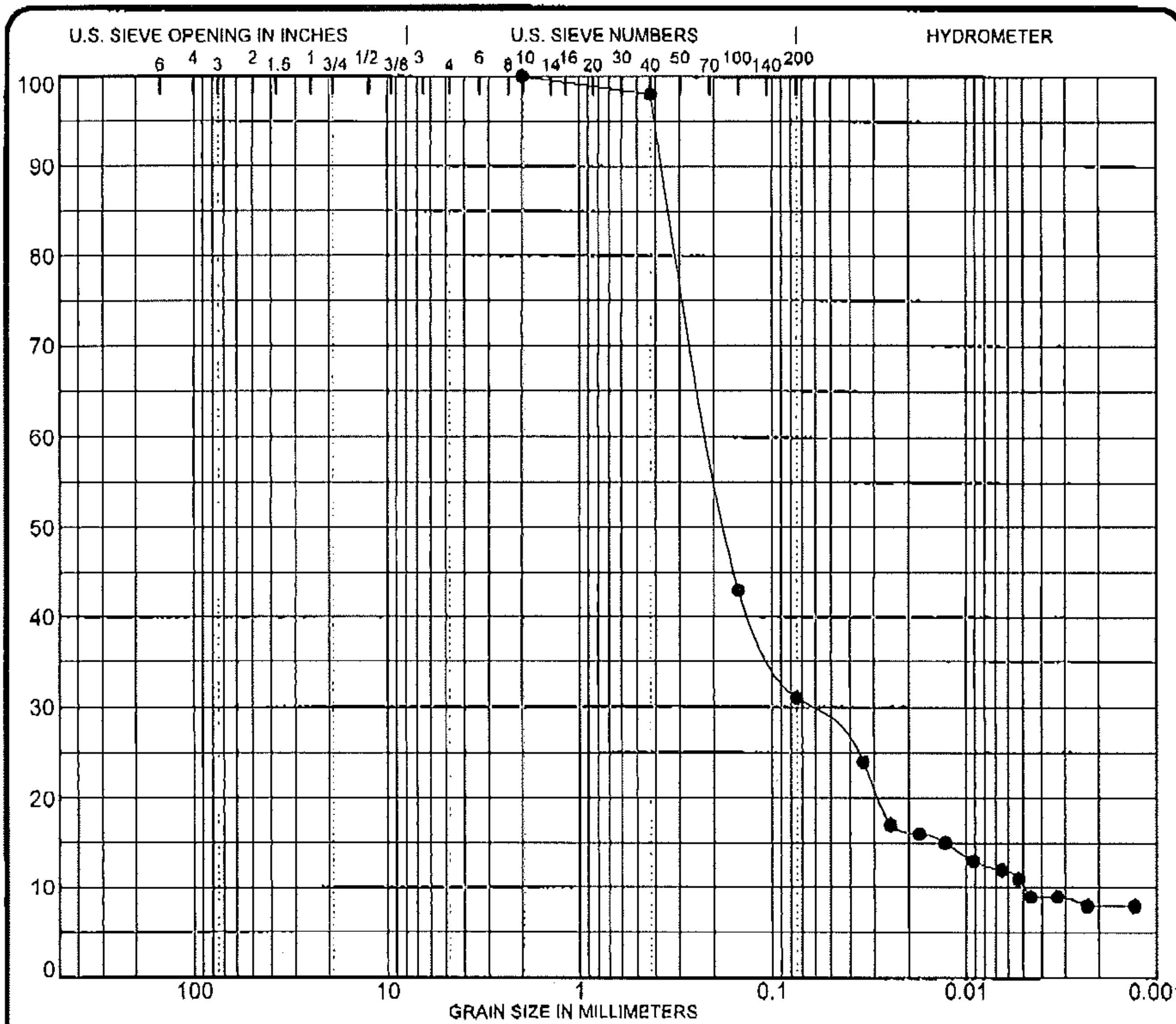
JOB NO. L - 76,757
DATE May 20, 2011

SB1

SOILGENR 76757.GPJ TSC ALL.GDT 5/20/11

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-1	3 inch	100	Gray clayey SAND (SC)			
Sample: E	2	100				
Depth: 37.0'-38.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	69	23	8
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	100	30.4	22	14	8
	# 40	98				
	# 100	43				
	# 200	31				

PROJECT Geotechnical Testing
LOCATION ,

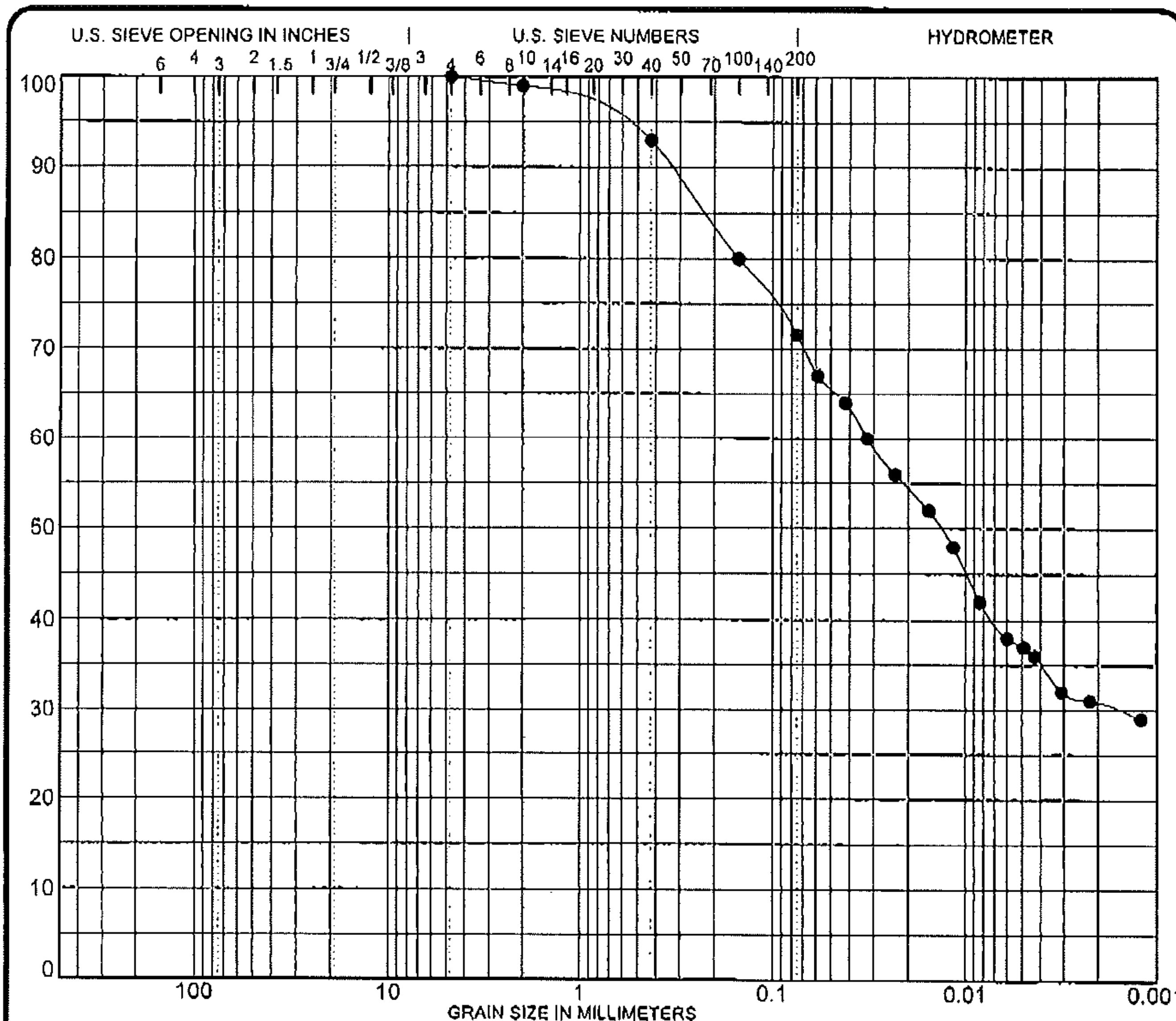
JOB NO. L - 76,757
DATE May 20, 2011

SB1

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC ALL.GDT 5/20/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS
Boring: SB-2	3 inch	100
Sample: A	2	100
Depth: 8.0'-9.0'	1 1/2	100
	1	100
NOTES:	3/4	100
	3/8	100
	# 4	100
	# 10	99
	# 40	93
	# 100	80
	# 200	72

SOIL CLASSIFICATION

Brownish gray silty CLAY, some sand
(CL)

%GRAVEL	%SAND	%SILT	%CLAY
0	28	41	31

MC%		LL	PL	PI
15.7		46	12	34

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LOCATION ,
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DATE May 20, 2011

SB2

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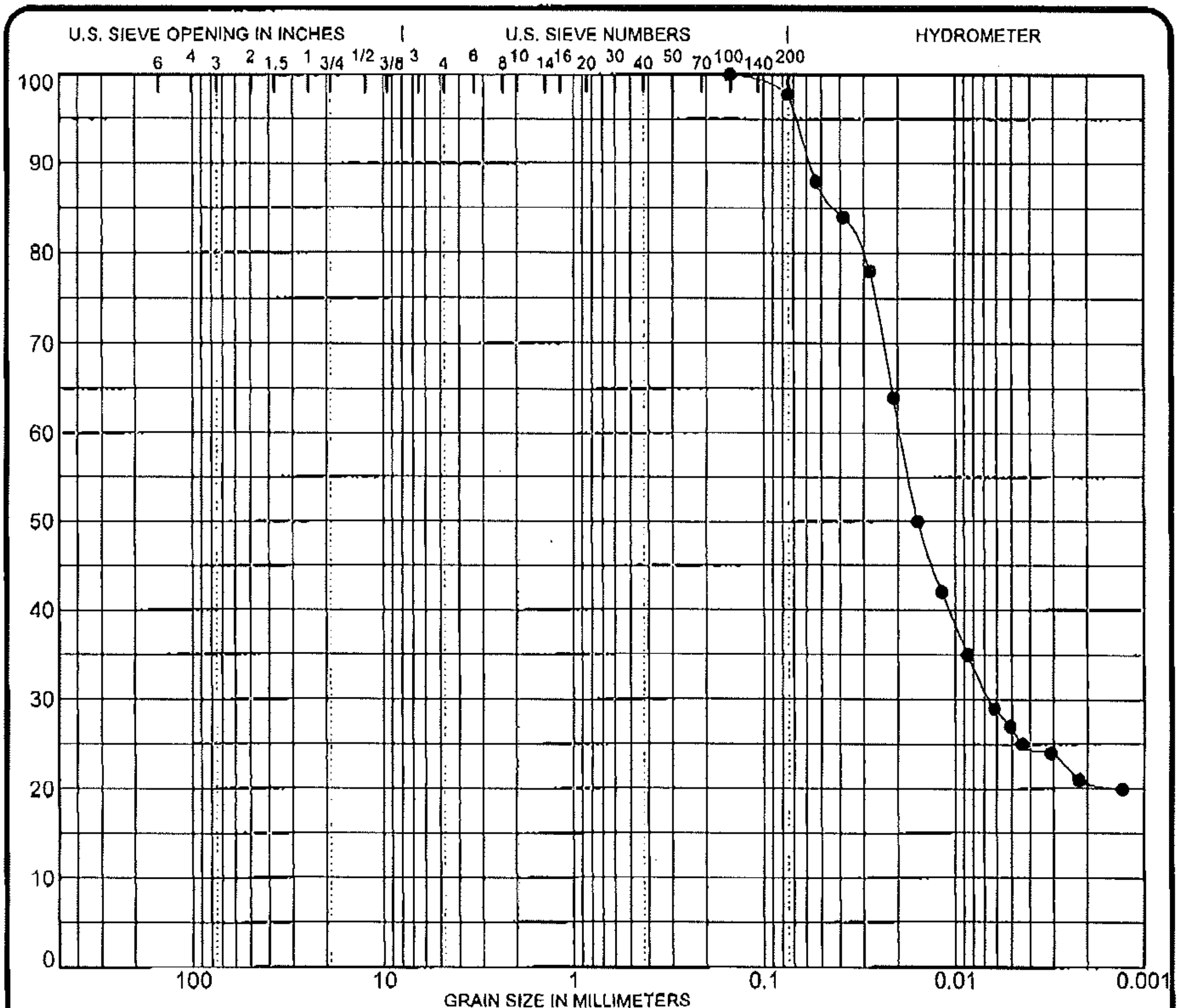
SOIL DATA SHEET
Testing Service Corporation
Carol Stream, IL 60188



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-2	3 inch	100	Dark gray very silty CLAY, trace sand			
Sample: B	2	100	(CL)			
Depth: 28.0'-29.0	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	2	77	21
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	100	35.1	42	18	24
	# 40	100				
	# 100	100				
	# 200	98				

PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 20, 2011

SB2

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/20/11

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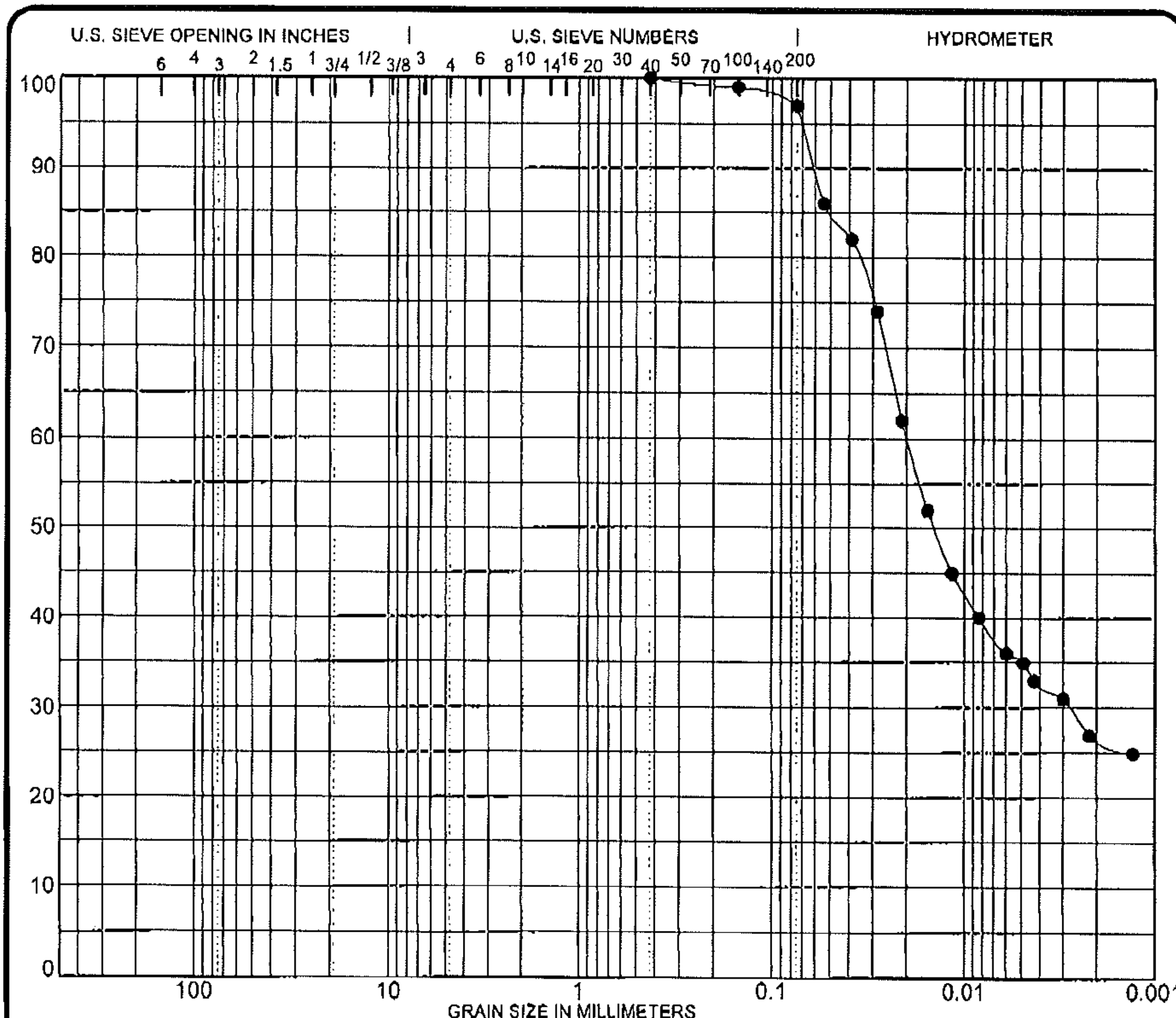


COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-2	3 inch	100	Dark gray silty CLAY, trace sand (CH)
Sample: C	2	100	
Depth: 32.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	100	
	# 4	100	
	# 10	100	
	# 40	100	
	# 100	99	
	# 200	97	

%GRAVEL	%SAND	%SILT	%CLAY
0	3	70	27

MC%		LL	PL	PI
32.9		51	16	35

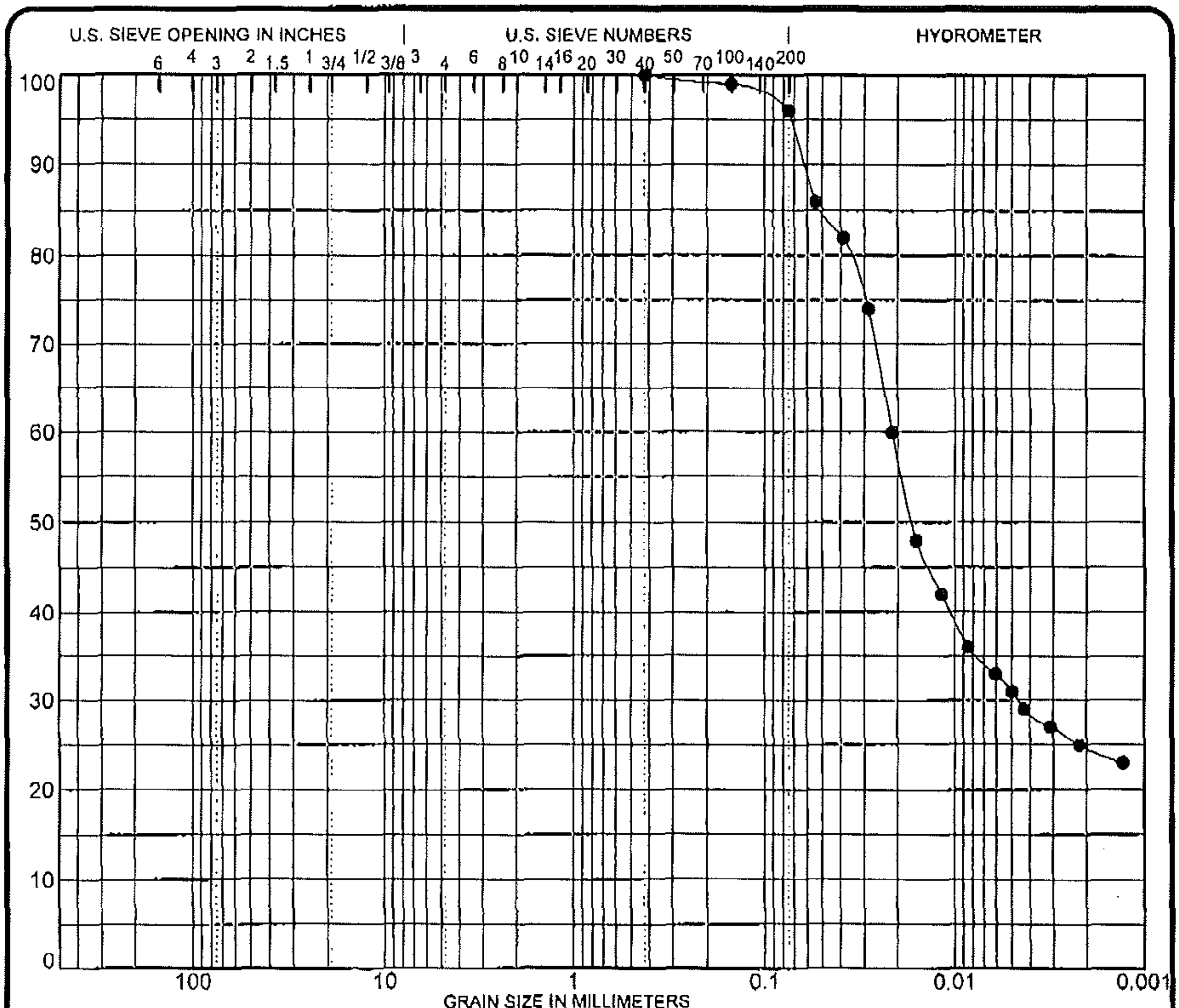
PROJECT Geotechnical Testing
LOCATION ,
SB2

JOB NO. L-76,757
DATE May 20, 2011

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/20/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-3	3 inch	100	Dark gray very silty CLAY, trace sand
Sample: A	2	100	(CL)
Depth: 38.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	100	
	# 4	100	
	# 10	100	
	# 40	100	
	# 100	99	
	# 200	96	

%GRAVEL	%SAND	%SILT	%CLAY
0	4	71	25

MC%		LL	PL	PI
34.4		46	15	31

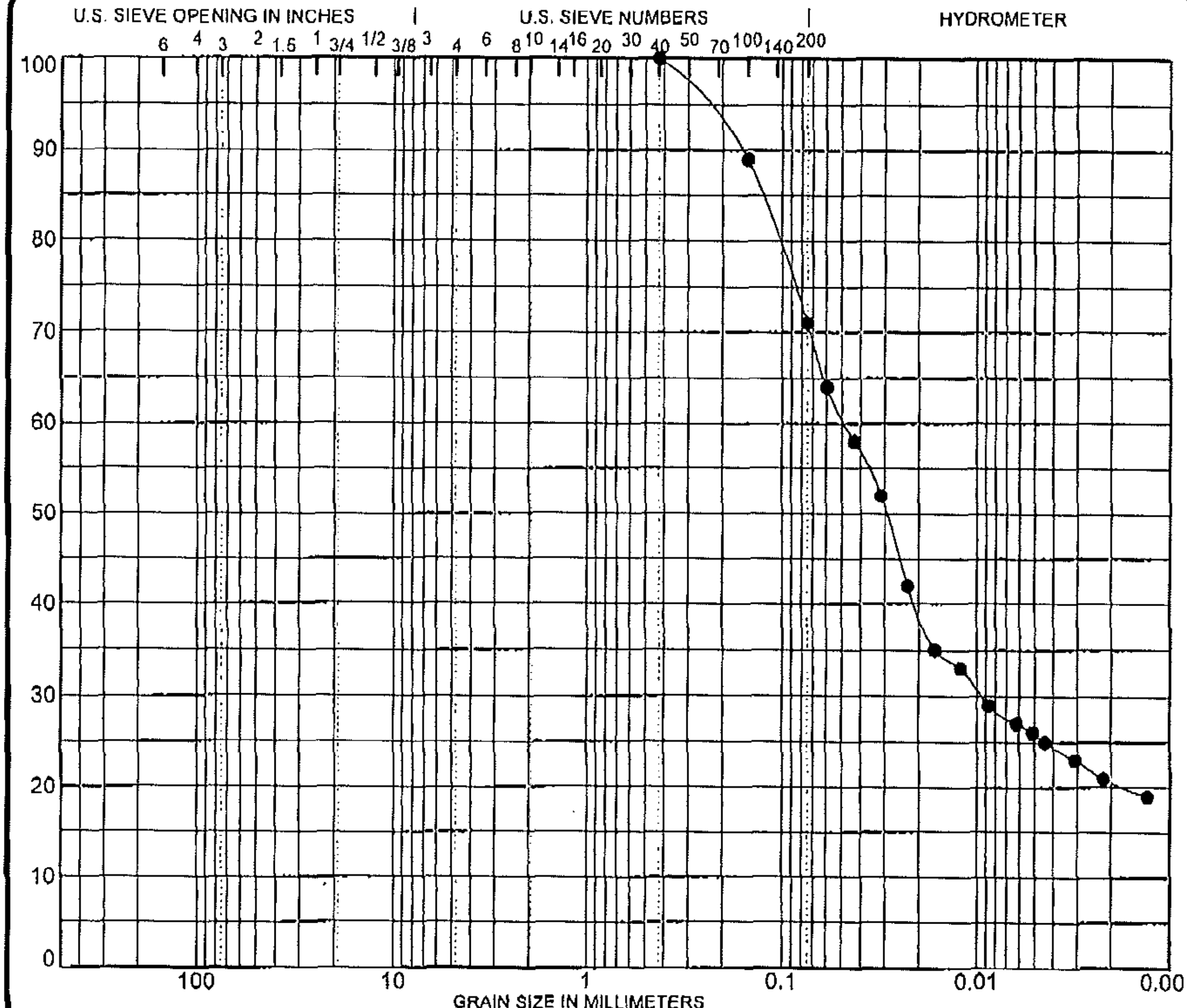
PROJECT Geotechnical Testing
LOCATION ,

JOB NO. L - 76,757
DATE May 20, 2011

SB3

SOILGENR 76757.GPJ TSC_ALL.GDT 5/20/11

SOIL DATA SHEET
Testing Service Corporation
Carol Stream, IL 60188



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-4	3 inch	100	Dark gray silty CLAY, some sand (CL)
Sample: A	2	100	
Depth: 34.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	100	
	# 4	100	
	# 10	100	
	# 40	100	
	# 100	89	
	# 200	71	

%GRAVEL	%SAND	%SILT	%CLAY
0	29	50	21

MC%		LL	PL	PI
24.1		41	12	29

PROJECT Geotechnical Testing
LOCATION ,
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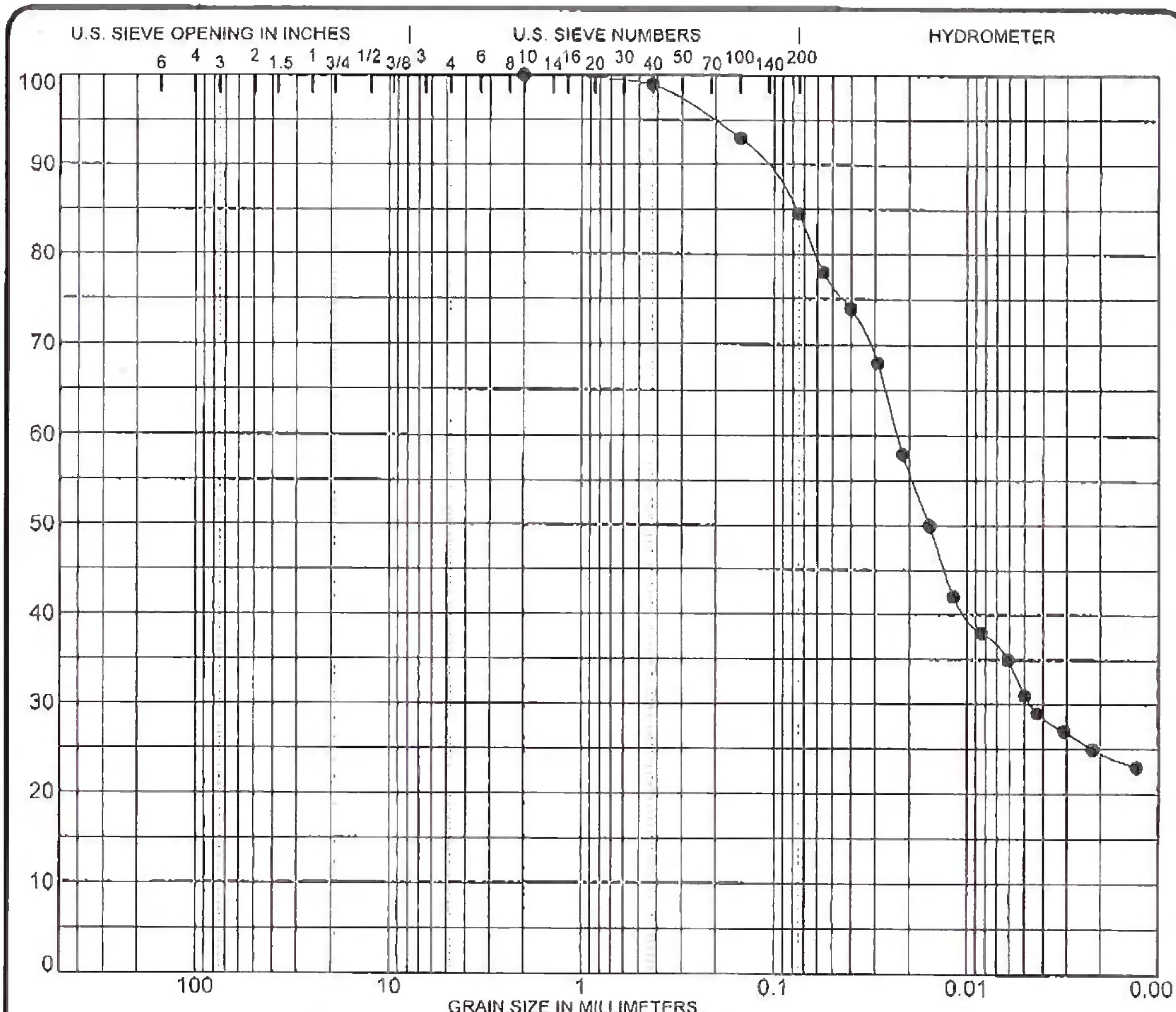
DATE May 20, 2011

SB4

SOILGENR 76757.GPJ TSC ALL.GDT 5/20/11

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

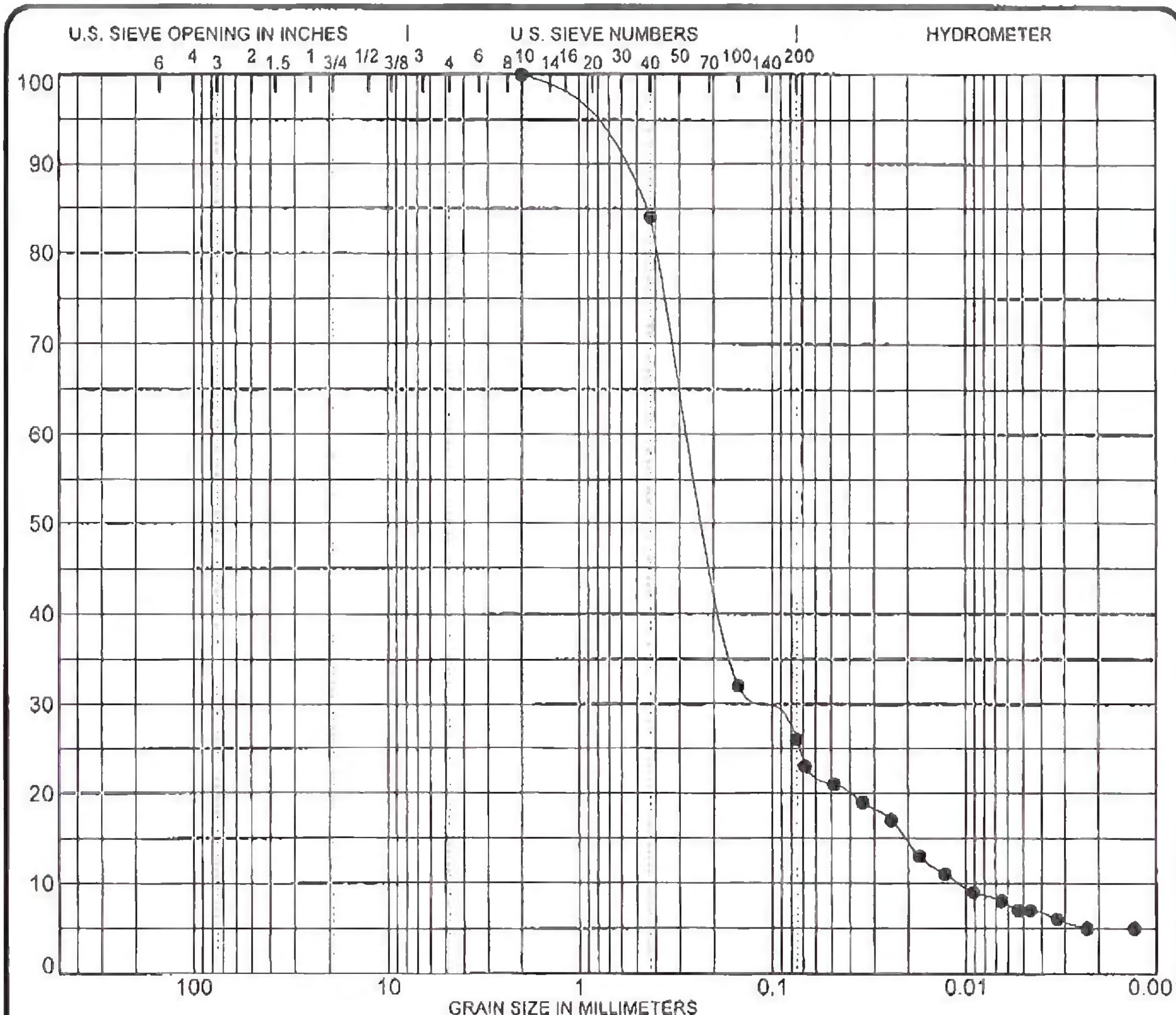
SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION				
Boring: SB-5	3 inch	100	Gray very silty CLAY, little sand (CL)				
Sample: A	2	100					
Depth: 34.0'	1 1/2	100					
	1	100	%GRAVEL	%SAND	%SILT	%CLAY	
NOTES:	3/4	100	0	15	60	25	
	3/8	100					
	# 4	100	MC%		LL	PL	PI
	# 10	100	23.3		43	16	27
	# 40	99					
	# 100	93					
	# 200	85					

PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 23, 2011

SB5

SOIL DATA SHEET
Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC AL1.GDT 5/23/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION				
Boring: SB-6	3 inch	100	Gray clayey SAND (SC)				
Sample: A	2	100					
Depth: 16.0'-17.0'	1 1/2	100					
	1	100	%GRAVEL	%SAND		%SILT	%CLAY
NOTES:	3/4	100	0	74		21	5
	3/8	100					
	# 4	100	MC%		LL	PL	PI
	# 10	100	24.6		16	13	3
	# 40	84					
	# 100	32					
	# 200	26					

PROJECT **Geotechnical Testing** JOB NO. **L - 76,757**

LOCATION , DATE **May 23, 2011**

SB6

SOIL DATA SHEET

Testing Service Corporation

Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC ALL.GDT 5/23/11

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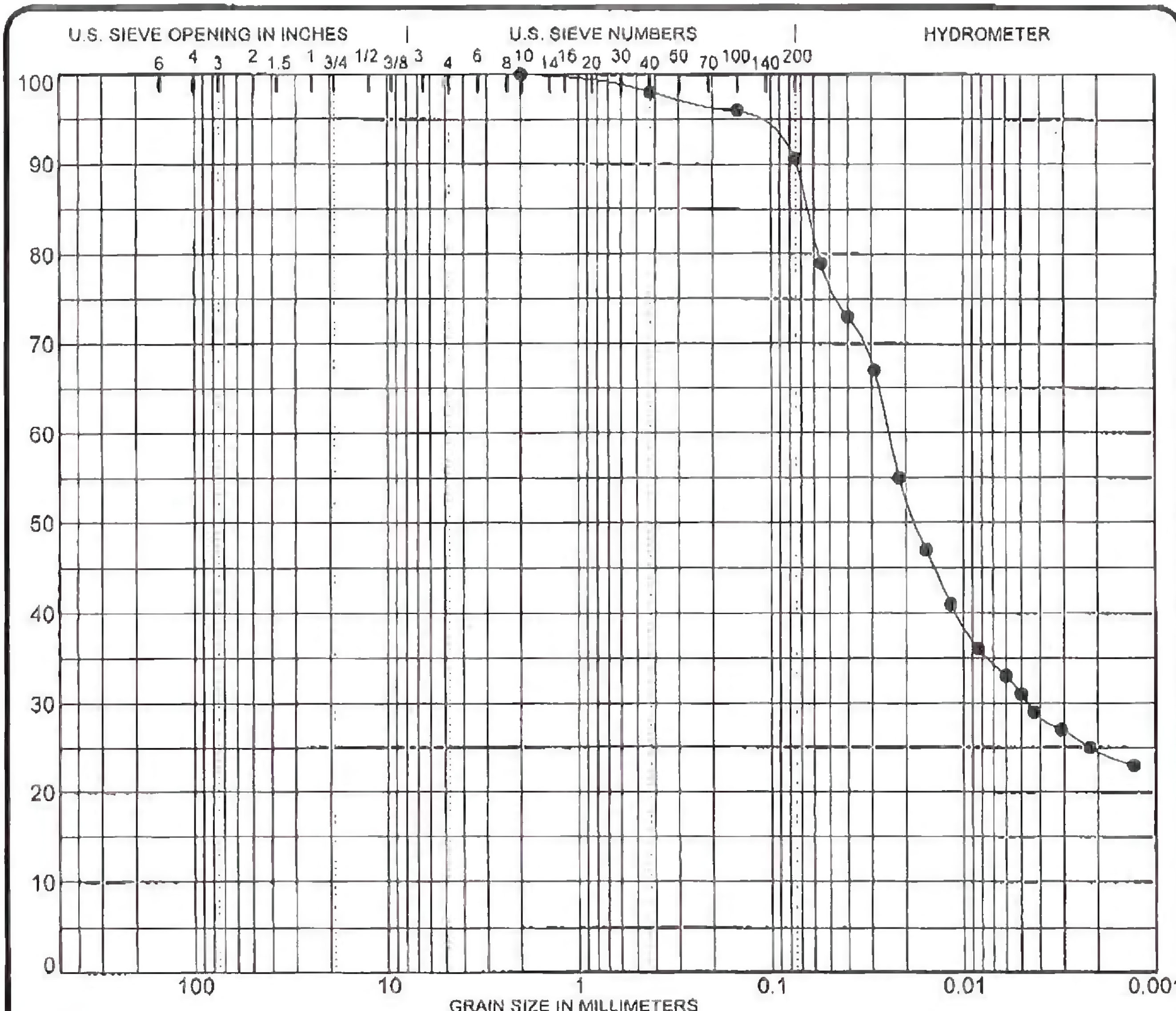

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-6	3 inch	100	Brownish gray very silty CLAY, trace sand			
Sample: B	2	100	(CL)			
Depth: 28.0'-29.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	9	66	25
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	100	28.3	43	13	30
	# 40	98				
	# 100	96				
	# 200	91				

PROJECT Geotechnical Testing
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SB6

SOILGENR 76757.GPJ TSC_ALL.GDT 5/23/11

SOIL DATA SHEET

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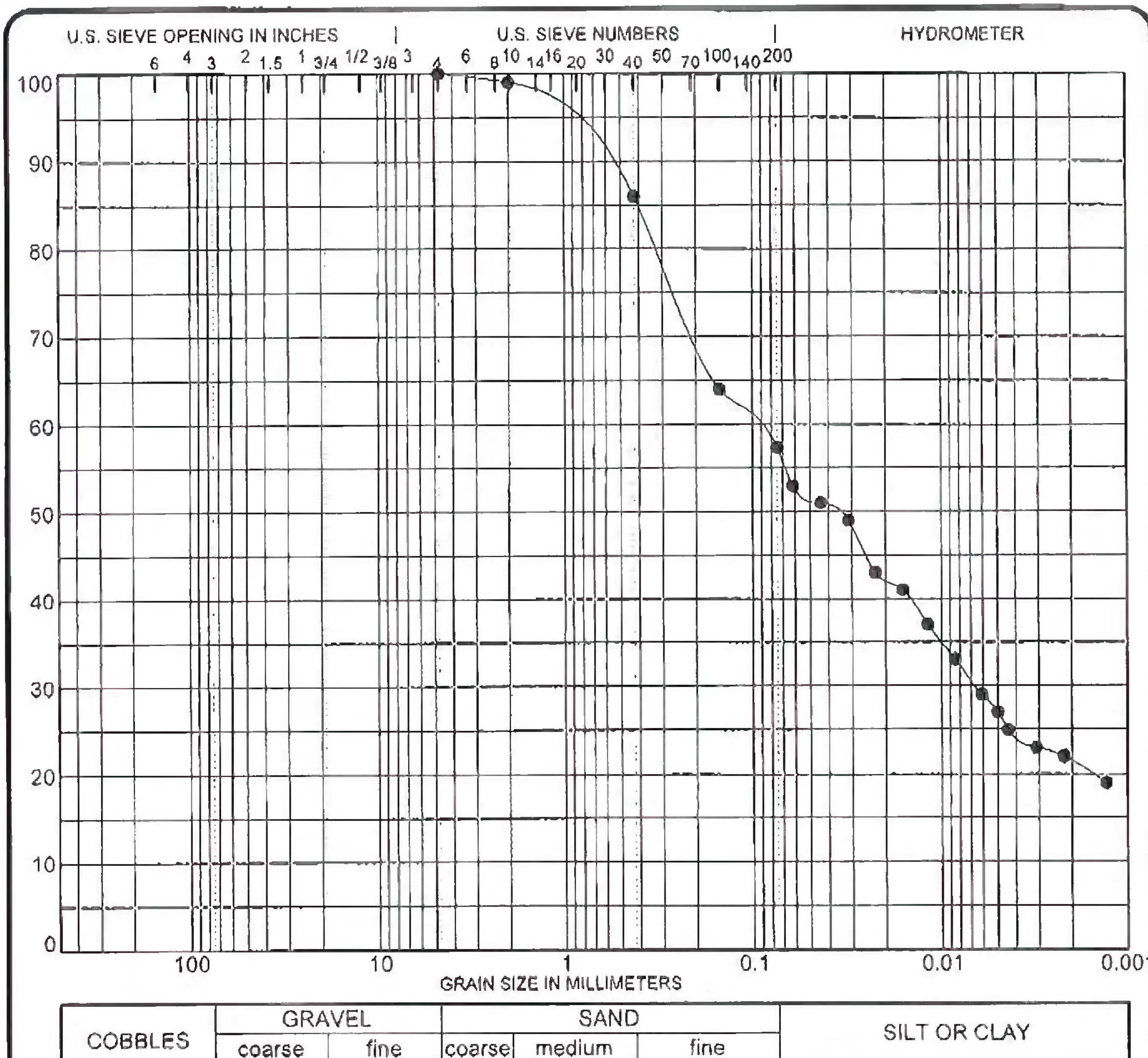

SPECIMEN IDENTIFICATION	SIEVE	% PASS
Boring: SB-8	3 inch	100
Sample: A	2	100
Depth: 10.0'	1 1/2	100
	1	100
NOTES:	3/4	100
	3/8	100
	# 4	100
	# 10	99
	# 40	86
	# 100	64
	# 200	57

SOIL CLASSIFICATION

Gray sandy CLAY (CL)

%GRAVEL	%SAND	%SILT	%CLAY
0	43	36	21

MC%		LL	PL	PI
21.6		36	12	24

PROJECT Geotechnical Testing
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DATE May 23, 2011

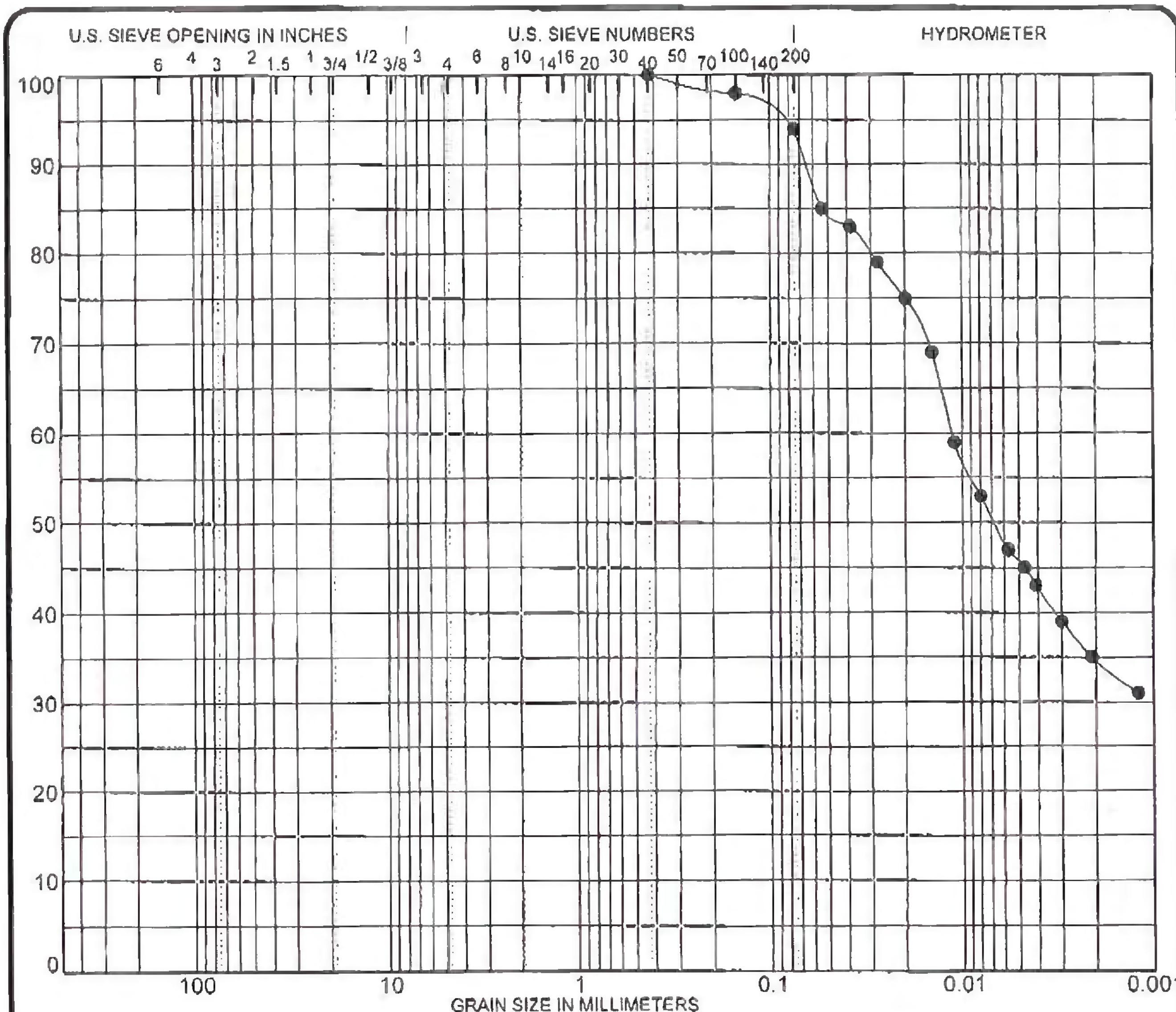
SB8

SOIL DATA SHEET

Testing Service Corporation

Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/23/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION				
Boring: SB-8	3 inch	100	Gray very silty CLAY, trace sand (CL)				
Sample: B	2	100					
Depth: 20.0'	1 1/2	100					
	1	100	%GRAVEL	%SAND	%SILT	%CLAY	
NOTES:	3/4	100	0	6	59	35	
	3/8	100					
	# 4	100	MC%		LL	PL	PI
	# 10	100	31.1		56	19	37
	# 40	100					
	# 100	98					
	# 200	94					

PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 23, 2011

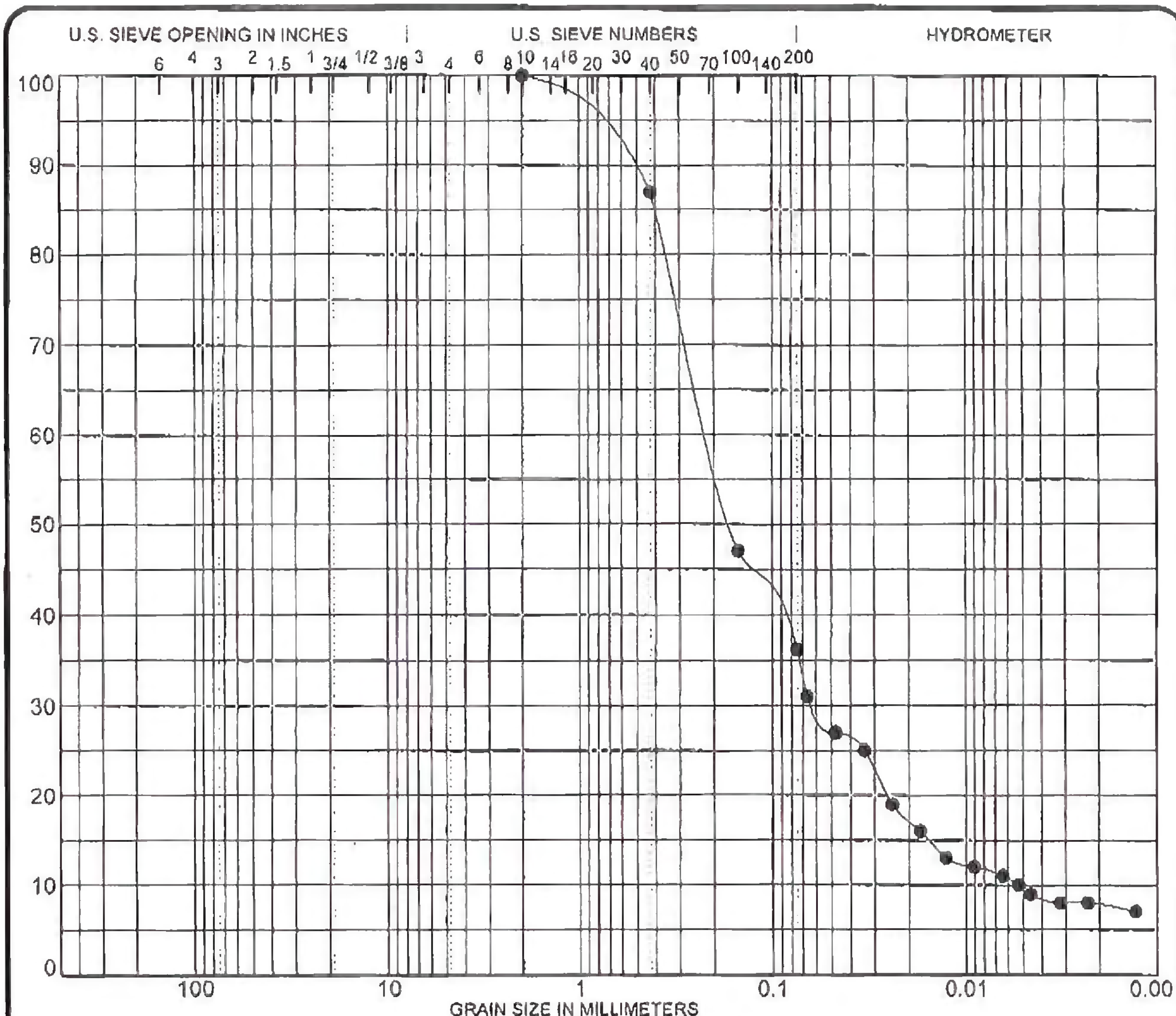
SB8

SOIL DATA SHEET

Testing Service Corporation

Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC ALL.GDT 5/23/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS
Boring: SB-8	3 inch	100
Sample: C	2	100
Depth: 22.0'	1 1/2"	100
	1	100
NOTES:	3/4	100
	3/8	100
	# 4	100
	# 10	100
	# 40	87
	# 100	47
	# 200	36

SOIL CLASSIFICATION

Gray clayey SAND (SC)

%GRAVEL	%SAND	%SILT	%CLAY
0	64	28	8

MC%		LL	PL	PI
26.9		21	13	8

PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 23, 2011

SB8

SOILGENR 76757.GPJ TSC ALL.GDT 5/23/11

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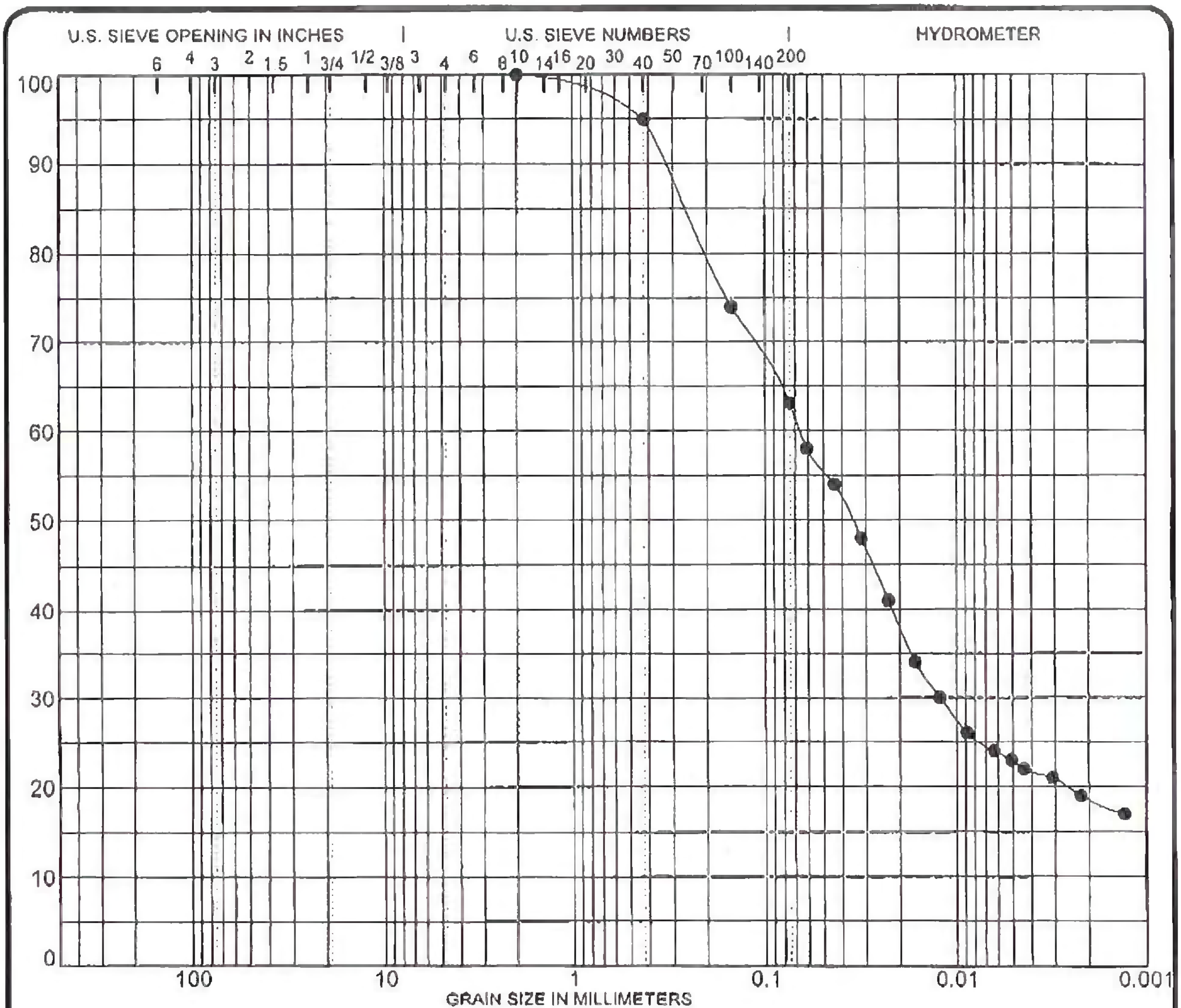
Carol Stream, IL 60188



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-9	3 inch	100	Brownish gray sandy CLAY (CL)			
Sample: A	2	100				
Depth: 18.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	37	44	19
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	100	34.0	35	13	22
	# 40	95				
	# 100	74				
	# 200	63				

PROJECT Geotechnical Testing
LOCATION ,

JOB NO. L - 76,757
DATE May 23, 2011

SB9

SOILGENR 76757.GPJ TSC_ALL.GDT 5/23/11

SOIL DATA SHEET

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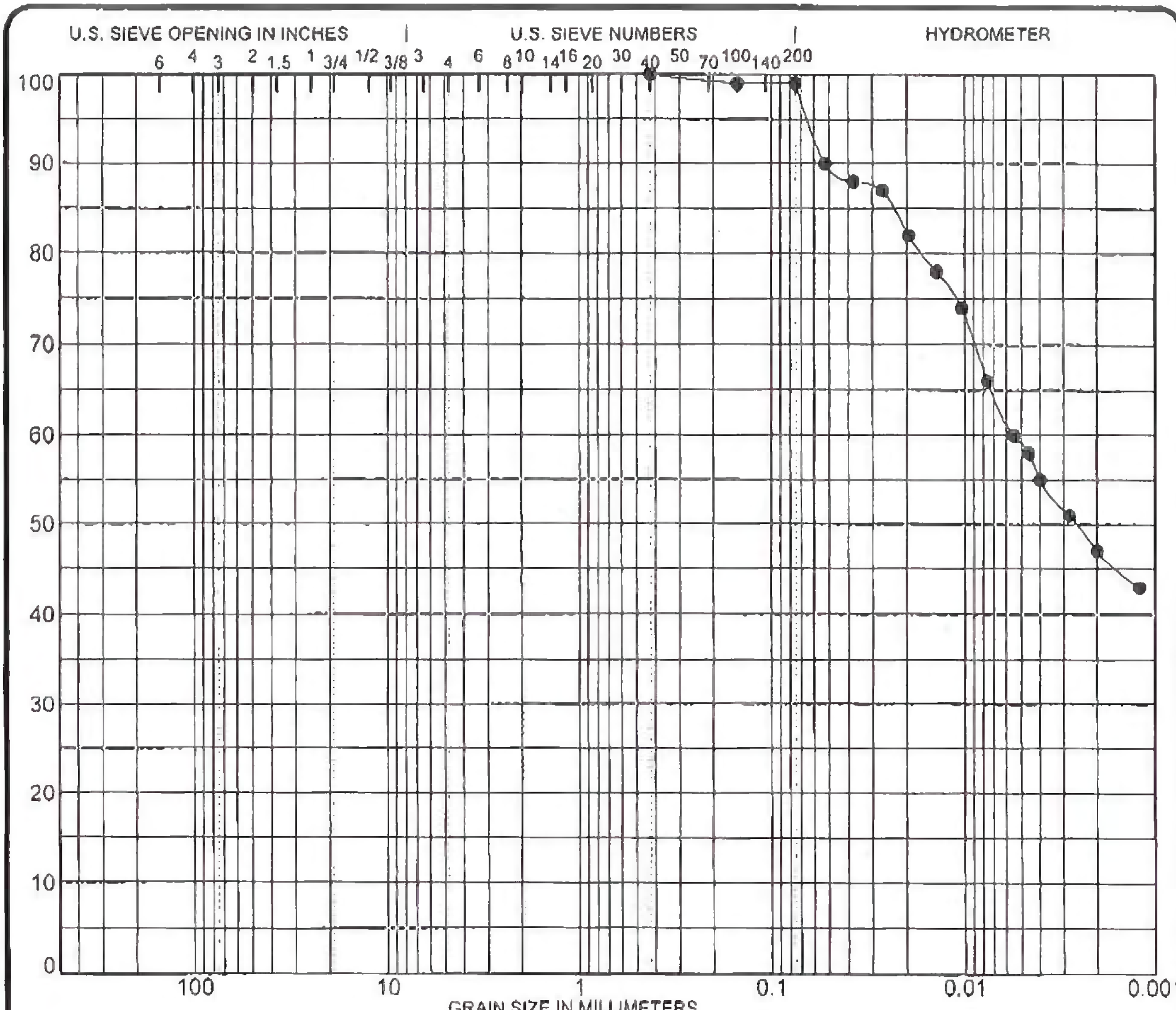

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS
Boring: SB-10	3 inch	100
Sample: A	2	100
Depth: 20.0'	1 1/2	100
	1	100
NOTES:	3/4	100
	3/8	100
	# 4	100
	# 10	100
	# 40	100
	# 100	99
	# 200	99

SOIL CLASSIFICATION

Brownish gray silty CLAY, trace sand
(CH)

%GRAVEL	%SAND	%SILT	%CLAY
0	1	52	47

MC%		LL	PL	PI
26.9		74	15	59

PROJECT Geotechnical Testing
LOCATION ,
SB10

JOB NO. L - 76,757
DATE May 23, 2011

SOIL DATA SHEET
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Carol Stream, IL 60188

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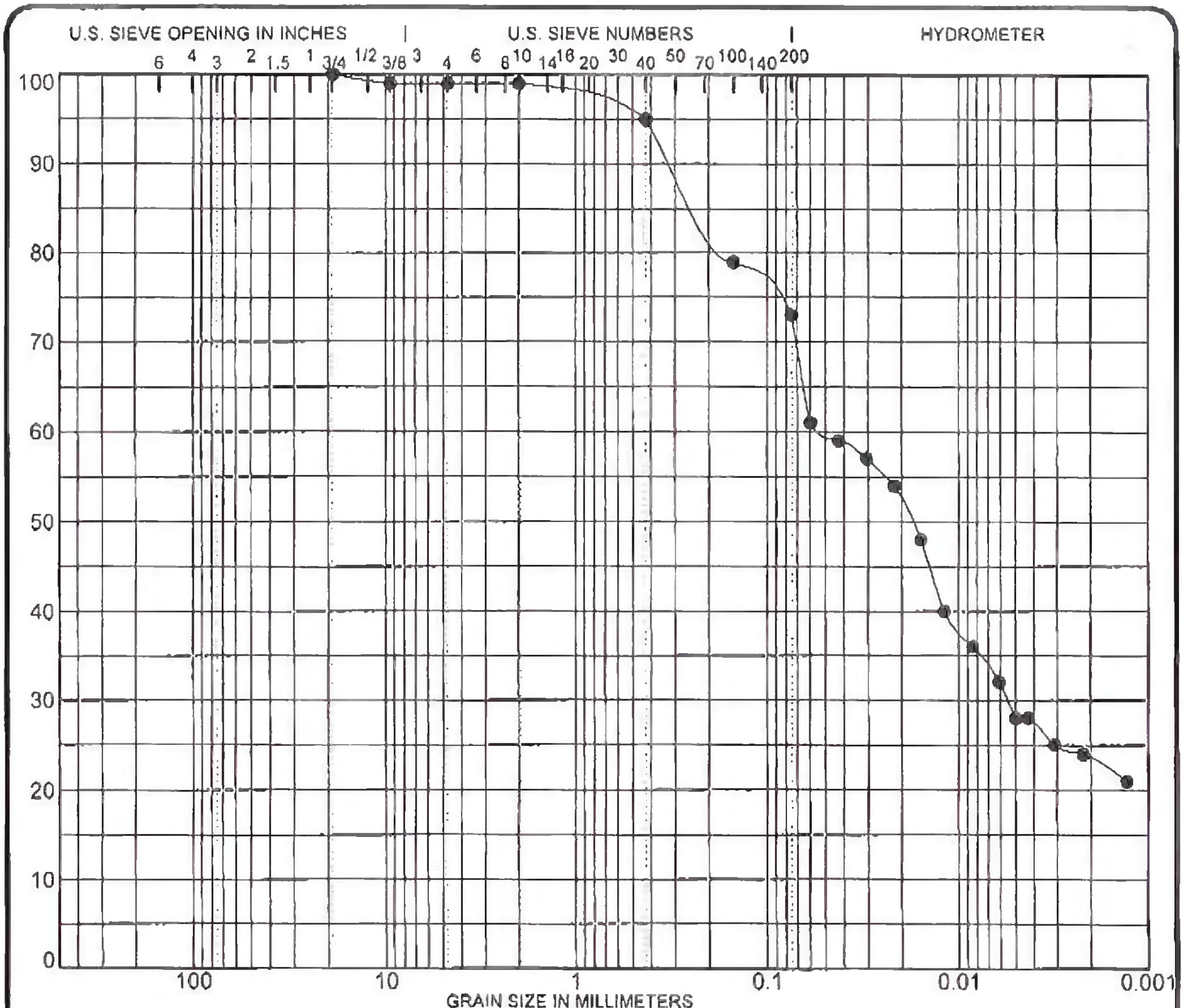

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-12	3 inch	100	Gray silty CLAY, some sand, trace gravel			
Sample: A	2	100	(CL)			
Depth: 23.0'-24.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	1	26	50	23
	3/8	99				
	# 4	99	MC%	LL	PL	PI
	# 10	99	35.9	42	16	26
	# 40	95				
	# 100	79				
	# 200	73				

PROJECT Geotechnical Testing
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JOB NO. L - 76,757
DATE May 23, 2011

SB12

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SOIL DATA SHEET

Testing Service Corporation

Carol Stream, IL 60188

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Appendix F

Initial Safety Factor Assessment (August 2016)

Safety Factor Assessment

Ash Seal Pond	
Safety Factor under Long-Term, Maximum Storage Pool Loading Condition	The Ash Seal Pond is a zero discharge pond and does not contain water under normal storage pool conditions. The lowest surface in the pond is elevation 531 feet above mean sea level (amsl) and the maximum storage pool assigned for this pond is elevation 526 feet amsl. The minimum calculated safety factor for this condition is 2.5. This exceeds the minimum required safety factor of 1.5.
Safety Factor under Maximum Surcharge Pool Loading Condition	This zero discharge pond will contain the 1,000-year design storm without discharge. Neglecting infiltration through sand at the base of the pond, the pool elevation for the design 1,000-year storm is elevation 533.4 feet amsl. The minimum calculated safety factor for this condition is 2.2. This exceeds the minimum required safety factor of 1.4.
Seismic Safety Factor	The CCR unit has a surface peak ground acceleration of 0.105 g. Based on this value, the minimum calculated seismic safety factor is 1.9. This exceeds the minimum required safety factor of 1.0.
Liquefaction Safety Factor	Based on the analyses, the CCR unit embankment and foundation clay and dense sand soils will not liquefy during the design earthquake. A post-liquefaction slope stability assessment for the CCR unit is not required.

Main Ash Pond	
Safety Factor under Long-Term, Maximum Storage Pool Loading Condition	Daily flow to the CCR unit maintains a storage pool at elevation 531.5 feet amsl. The minimum calculated safety factor for this condition is 3.9. This exceeds the minimum required safety factor of 1.5.
Safety Factor under Maximum Surcharge Pool Loading Condition	The CCR unit pool elevation for the design 1,000-year storm is elevation 533.4 feet amsl. The minimum calculated safety factor for this condition is 3.8. This exceeds the minimum required safety factor of 1.4.
Seismic Safety Factor	The CCR unit has a surface peak ground acceleration of 0.105 g. Based on this value, the minimum calculated seismic safety factor is 2.6. This exceeds the minimum required safety factor of 1.0.
Liquefaction Safety Factor	Based on the analyses, the CCR unit embankment and foundation clay soils will not liquefy during the design earthquake. A post-liquefaction slope stability assessment for the CCR unit is not required.

Economizer Pond	
Safety Factor under Long-Term, Maximum Storage Pool Loading Condition	The static water level in the Economizer Pond is the same as the Upper Ash Pond at elevation 528 feet amsl. The minimum calculated safety factor for this condition is 2.1. This exceeds the minimum required safety factor of 1.5.
Safety Factor under Maximum Surcharge Pool Loading Condition	The Economizer Pond will route the 1,000-year design storm flow with essentially no storage. The maximum surcharge pool level will correspond to the rise in water to elevation 531 feet amsl in the Upper Ash Pond. The minimum calculated safety factor for this condition is 2.1. This exceeds the minimum required safety factor of 1.4.
Seismic Safety Factor	The CCR unit has a surface peak ground acceleration of 0.105 g. Based on this value, the minimum calculated seismic safety factor is 1.2. This exceeds the minimum required safety factor of 1.0.
Liquefaction Safety Factor	Based on the analyses, the CCR unit western portion of the north embankment and foundation materials consisting of clay and medium dense CCR will not liquefy during the design earthquake. The eastern portion of the north embankment consists of CCR overlying a very loose layer of CCR that is likely to liquefy during the design earthquake. Information obtained from borings was used to estimate the post-liquefaction strength of the liquefied layer. Based on analysis of the eastern portion of the north embankment, the minimum post-liquefaction safety factor is 1.4. This exceeds the minimum required safety factor of 1.2.

Upper Ash Pond	
Safety Factor under Long-Term, Maximum Storage Pool Loading Condition	Daily flow to the CCR unit maintains a storage pool at elevation 528 feet amsl. The minimum calculated safety factor for this condition is 3.3. This exceeds the minimum required safety factor of 1.5.
Safety Factor under Maximum Surcharge Pool Loading Condition	The CCR unit pool elevation for the design 1,000-year storm is elevation 530.3 feet amsl. The minimum calculated safety factor for this condition is 3.2. This exceeds the minimum required safety factor of 1.4.
Seismic Safety Factor	The CCR unit has a surface peak ground acceleration of 0.105 g. Based on this value, the minimum calculated seismic safety factor is 2.4. This exceeds the minimum required safety factor of 1.0.
Liquefaction Safety Factor	Based on the analyses, the CCR unit embankment and foundation clay soils will not liquefy during the design earthquake. A post-liquefaction slope stability assessment for the CCR unit is not required.

ALLIANT ENERGY
Interstate Power and Light Company
Burlington Generating Station

CCR SURFACE IMPOUNDMENT

SAFETY FACTOR ASSESSMENT

Report Issued: August 25, 2016
Revision 0

HARD HAT SERVICES™
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EXECUTIVE SUMMARY

This Safety Factor Assessment (Report) is prepared in accordance with the requirements of the United States Environmental Protection Agency (USEPA) published Final Rule for Hazardous and Solid Waste Management System – Disposal of Coal Combustion Residual (CCR) from Electric Utilities (40 CFR Parts 257 and 261, also known as the CCR Rule) published on April 17, 2015 and effective October 19, 2015.

This Report assess the safety factors of each CCR unit at the IPL – Burlington Generating Station in Burlington, Iowa in accordance with §257.73(b) and §257.73(e) of the CCR Rule. For purposes of this Report, "CCR unit" refers to existing CCR surface impoundments.

Primarily, this Report assesses if each CCR surface impoundment achieves the minimum safety factors, which include:

- Static factor of safety under long-term, maximum storage pool loading condition,
- Static factor of safety under the maximum surcharge pool loading condition,
- Seismic factor of safety; and,
- Post-Liquefaction factor of safety for embankments constructed of soils that will experience liquefaction during the design earthquake.

Table of Contents

Figures

Appendices

1 Introduction

The owner or operator of the Coal Combustion Residual (CCR) unit must conduct an initial and periodic safety factor assessments to determine if each CCR surface impoundment achieves the minimum safety factors, which include:

- Static factor of safety under long-term, maximum storage pool loading condition,
- Static factor of safety under the maximum surcharge pool loading condition,
- Seismic factor of safety; and,
- Post-Liquefaction factor of safety for embankments constructed of soils that have susceptibility to liquefaction.

This Report has been prepared in accordance with the requirements of §257.73(b) and §257.73(e) of the CCR Rule.

1.1 CCR Rule Applicability

The CCR Rule requires a periodic safety factor assessment by a qualified professional engineer (PE) for existing CCR surface impoundments with a height of 5 feet or more and a storage volume of 20 acre-feet or more or the existing CCR surface impoundment has a height of 20 feet or more (§257.73(b)).

1.2 Safety Factor Assessment Applicability

The Burlington Generating Station (BGS) in Burlington, Iowa (Figure 1) has four existing CCR surface impoundments that meet the requirements of §257.73(b)(1) or §257.73(b)(2) of the CCR Rule, which are identified as follows:

- BGS Ash Seal Pond
- BGS Main Ash Pond
- BGS Economizer Pond
- BGS Upper Ash Pond

2 FACILITY DESCRIPTION

The following sub-section provides a summary description of the facility and existing CCR surface impoundments located at BGS.

BGS is located southeast of the City of Burlington, Iowa on the western shore of the Mississippi River in Des Moines County, at 4282 Sullivan Slough Road, Burlington, Iowa (Figure 1). BGS is a fossil-fueled electric generating station consisting of one steam electric generating unit and four combustion turbine units. Sub-bituminous coal is the primary fuel for producing steam, and natural gas is used for the combustion turbines. The burning of coal in the steam electric unit produces CCR. The CCR at BGS is categorized into three types, bottom ash, economizer ash, and precipitator fly ash.

Date of Initial Facility Operations:	1968
NPDES Permit Number:	IA29-00-1-01
Facility Title V Operating Permit:	98-TV-023R1-M004
Latitude / Longitude:	40°44’29”N 91°07’04”W
Site Coordinates:	Section 29, Township 69 North, Range 02 West

2.1 BGS Ash Seal Pond

The BGS Ash Seal Pond is located south of the generating plant and east of the BGS Main Ash Pond. The CCR, in 1968, was originally managed by discharging into the BGS Ash Seal Pond for settling. Presently, the BGS Ash Seal Pond only receives storm water runoff from the surrounding area associated with the fly ash storage silo. The BGS Ash Seal Pond also may receive facility process water, such as ash seal water, but only if there is an issue with the ash seal water pumps. At the time of the initial annual inspection on October 26, 2015 this CCR surface impoundment did not contain standing water.

The surface area of the BGS Ash Seal Pond is approximately 5.7 acres and has an embankment height of approximately 12 feet from the crest to the toe of the downstream slope. The embankment crest is at elevation 534 the same as the adjacent plant site grade and equivalent to the 100 year flood water elevation of the Mississippi River. The interior storage depth of the BGS Ash Seal Pond is approximately 12 feet. If water were present, the total volume of impounded CCR and water within the BGS Ash Seal Pond would be approximately 97,000 cubic yards, which would include general fill that has been added in the northeast corner of the impoundment. The original outfall for the impoundment is sealed to prevent discharge to the Mississippi River and the impoundment normally contains no water. Rainfall that accumulates exfiltrates through the bottom of the impoundment. A manually operated pump is available to lift storm water to the adjacent BGS Main Ash Pond, if necessary.

2.2 BGS Main Ash Pond

The BGS Main Ash Pond is located southwest of the generating plant and west of the BGS Ash Seal Pond. The CCR, prior to being sluiced to the BGS Main Ash Pond, was originally managed in the BGS Ash Seal Pond in 1968. In 1971, BGS managed CCR in the BGS Upper Ash Pond. In 1980, the BGS Main Ash Pond became the primary receiver of CCR, with the BGS Upper Ash Pond becoming a downstream receiver.

Presently, the BGS Main Ash Pond receives bottom ash that is sluiced from the generating plant to the northeast corner of the BGS Main Ash Pond. The sluiced bottom ash discharges into the northeast corner where the majority of the bottom ash settles out. The bottom ash that settles out is recovered for beneficial reuse. Hydrated fly ash is also stored within the BGS Main Ash Pond area prior to being sold as aggregate material for beneficial reuse. Fly ash from the on-site storage silo is no longer added to the embankment.

The water that is used to sluice the bottom ash into the BGS Main Ash Pond is routed towards the west end of the BGS Main Ash Pond. The water is discharged in batch quantities as bottom ash accumulates in the boiler and averages 1 cubic foot per second (cfs) on a daily basis. The water flows to the west along the north side of a road constructed out of bottom ash through the center of the BGS Main Ash Pond, Figure 2.

The water flows along the north side of the road until it reaches the west end where it transitions into a ponded area in the northwest corner of the BGS Main Ash Pond. The water in the northwest corner of the BGS Main Ash Pond flows through two 15 inch diameter corrugated metal culverts with identical invert elevation under the generating plant entrance road. The water discharges into a small channel in the southwest corner of the BGS Upper Ash Pond located north of the generating plant entrance road.

The surface area of the BGS Main Ash Pond is approximately 18.7 acres and has an embankment height of approximately 12 feet from the crest to the toe of the downstream slope. The embankment crest is at elevation 534 the same as the plant site grade and equivalent to the 100 year flood water elevation in the Mississippi River. The interior storage depth of the BGS Main Ash Pond is approximately 8 feet. The total volume of impounded CCR and water within the BGS Main Ash Pond at normal water operation elevation is approximately 240,000 cubic yards. Additional volume of impounded CCR, located in the eastern half of the BGS Main Ash Pond above the crest elevation of the embankment, includes the bottom ash storage area and C-stone embankment (hydrated fly ash). In 2008, the quantity of the additional CCR above the crest elevation of the embankment is approximately 104,000 cubic yards.

2.3 BGS Economizer Pond

The BGS Economizer Pond is located west of the generating plant and north of the BGS Main Ash Pond. In 1986, BGS constructed the BGS Economizer Pond in the southern and eastern portion of the original footprint of the BGS Upper Ash Pond. The impoundment has resulted from economizer ash that has been deposited since 1986, which created the economizer embankment which is higher than the embankments of the BGS Upper Ash Pond at approximately elevation 548.

Presently, the BGS Economizer Pond receives economizer ash. The economizer ash is sluiced from the generating plant to the east end of the BGS Economizer Pond via a 10-inch diameter polyvinyl chloride pipe at a flow rate of 1.5 cfs (including approximately

10% plant process water). The economizer ash settles out through the water column of the 0.4 acre BGS Economizer Pond while the water flows to the west. The water discharges from the BGS Economizer Pond through an 18-inch diameter high-density polyethylene pipe into a storm water and process water treatment channel located along the south side of the economizer embankment.

The storm water and process water treatment channel receives runoff from 8 acres surrounding the generating plant. The collected storm water drains into a pump vault located at the toe of the downstream slope of the east embankment of the BGS Economizer Pond. Plant process water flows through an oil/water separator and receives influent flows from the plant floor drains and water treatment process water. After the oil/water separator, the process water discharges into the pump vault. The storm water and process water is then pumped from the vault up to the storm water treatment channel. The storm water treatment channel flows to the west along the south side of the economizer embankment until it discharges through an 18-inch diameter high-density polyethylene pipe located in the southwest corner of the economizer embankment. The water from the storm water treatment channel discharges into a small channel in the southwest corner of the BGS Upper Ash Pond located north of the generating plant entrance road.

The total surface area of the BGS Economizer Pond and economizer embankment is approximately 11 acres and has an embankment height of approximately 13 feet from the crest to the toe of slope on the CCR in the BGS Upper Ash Pond. The interior storage depth of the top of the economizer embankment to the bottom of the original footprint of the BGS Upper Ash Pond is approximately 27 feet. Thus, the total volume of impounded CCR and water within the BGS Economizer Pond including CCR already in place when the impoundment was established is approximately 480,000 cubic yards.

2.4 BGS Upper Ash Pond

The BGS Upper Ash Pond is located northwest of the generating plant and north of the BGS Main Ash Pond. In 1971, BGS began managing CCR in the BGS Upper Ash Pond. In 1980, the BGS Main Ash Pond became the primary receiver of CCR and the BGS Upper Ash Pond became a downstream receiver of the BGS Main Ash Pond.

Presently, the BGS Upper Ash Pond receives influent flows from the BGS Main Ash Pond, BGS Economizer Pond, and storm water and process water flow from the generating plant. The influent flows all discharge into a small channel located in the southwest corner of the BGS Upper Ash Pond. The water in the channel routed along the south side of the gravel dike of the BGS Upper Ash Pond until it discharges into the southwest corner of the BGS Upper Ash Pond water body.

The water flows through the BGS Upper Ash Pond water body to the northeast towards a 24-inch wide precast concrete Parshall flume that discharges into a concrete catch basin. The water in the catch basin flows through a 15-inch diameter polyvinyl chloride pipe and discharges into the BGS Lower Pond. Instrumentation associated with the BGS Upper Ash Pond includes a flow meter that monitors the discharges. The discharge from the concrete catch basin enters the Lower Pond. The Lower Pond contains the facility's National Pollution Discharge Elimination System (NPDES) Outfall 001. The water flows through the NPDES Outfall 001 hydraulic structure, which consists of cast in place weir box.

The total surface area of the BGS Upper Ash Pond is approximately 13.3 acres and has an embankment height of approximately 10 feet from the crest to the toe of the downstream slope. The elevation of the embankments is 531 feet, 3 feet lower than the 100 year flood elevation of the Mississippi River. The embankment is armored with cobble size stone on the crest and both outer and inner embankment slopes to prevent erosion of the embankment during overtopping from extreme flood stage of the Mississippi River. The interior storage depth of the BGS Upper Ash Pond is approximately 7 feet. The volume of impounded CCR and water within the BGS Upper Ash Pond at normal operation water elevation is approximately 150,000 cubic yards.

3 SAFETY FACTOR ASSESSMENT- §257.73(e)

This Report documents if each CCR surface impoundment achieves the minimum safety factors, which are identified on the table below.

Safety Factor Assessment	Minimum Safety Factor
Static Safety Factor Under Maximum Storage Pool Loading	1.50
Static Safety Factor Under Maximum Surcharge Pool Loading	1.40
Seismic Safety Factor	1.00
Post-Liquefaction Safety Factor	1.20

3.1 Safety Factor Assessment Methods

The safety factor assessment is completed with the two dimensional limit-equilibrium slope stability analyses program STABL5M (1996)[1]. The program analyzes many potential failure circles or block slides by random generation of failure surfaces using toe and crest search boundaries set for each analysis. The solution occurs by balancing the resisting forces along the failure plane due to Mohr-Columb failure strength parameters of friction angle and cohesion against the gravity forces. The gravity driving forces are divided into the resisting forces to produce a safety factor for the slope. The minimum of hundreds of searches is presented as the applicable safety factor of the embankment.

There are both total stress and effective stress friction angle and cohesion values for clay. For the total stress case clay has only cohesion. For effective stress clay has both cohesion and friction angle. When clay receives a load that is applied only briefly (i.e., earthquake or high water), it responds as a total stress soil. For long term loadings such as normal water elevation, the clay resistance to failure is based on effective stress parameters. Because effective stress clay parameters are not readily available from normal soil testing and because the total stress parameters for compacted and over consolidated clay yield a

[1] STABL User Manual by Ronald A. Siegel, Purdue University, June 4, 1975 and STABL% -- The SPENCER Method of Slices: Final Report, by J. R. Carpenter, Purdue University, August 28, 1985

conservative answer for safety factor, the static analysis with normal operating water elevation is performed with the total stress parameters for the clay components in the embankments.

3.1.1 Soil Conditions in and under the impoundments

The BGS is constructed on a natural levee deposit on the west back of the Mississippi River at River Mile 399. Numerous soil borings were installed for construction activities at the plant in 1962 and 2008, Figure 2. The borings are presented in Appendix A and indicate bedrock at elevation 450, very dense sand and gravel to elevation 470, and medium dense sand to elevation 510. Above 510 the plant area and BGS Ash Seal Pond have loose layers of silt and silty sand with compacted filled to bring the site grade to elevation 534.

Because there were no soil borings in the areas of the BGS Main Ash Pond, BGS Economizer Ash Pond, and BGS Upper Ash Pond, new geoprobe borings for soil samples and cone penetrometer borings for strength/density measurement were taken on the three ash ponds west of the plant site in 2011. The sample locations are shown on Figure 2 with the geoprobe boring logs in Appendix B and the Cone Penetrometer results in Appendix C. In addition to the borings, samples from the geoprobes were tested to determine water content, Atterberg limits, and grain size of the soils found above the medium dense sand layer at elevation 510. The laboratory test results are in Appendix D.

The 2011 results find a natural clay layer below the embankments of the ash ponds with plastic index greater than 20% and natural water content greater than 25%. The soil is a low plasticity clay deposited during river flooding in the backwater areas west of the plant site. The embankments of the BGS Main Ash Pond and the BGS Upper Ash Pond are constructed of clayey silt that was compacted over the natural clay deposit. From an interview with a long time staff member at the facility, it is understood that the clay borrow site was a rock quarry just west of the Station. The surface soil in the Burlington

Iowa area is loess with a glacial till found between the loess and limestone bedrock. The observed properties of the clay embankments confirm that loess is the likely source soil. In the BGS Economizer Pond, the imported clayey silt is found in the embankments constructed to raise the BGS Economizer Pond above the BGS Upper Ash Pond on the south, east, and west sides and on the western half of the north side. However, the eastern half of the north side embankment contains no imported clay and is CCR constructed on top of CCR in the BGS Upper Ash Pond.

The CPT data results for clay layers are assigned an undrained shear strength (cohesion) based on the procedure recommended by Robertson[2]. The undrained shear strength is:

$$S_u = (q_c - \alpha_0) / N_k$$

Where: S_u = undrained shear strength
qc = cone penetration pressure
α_0 = total vertical overburden stress
N_k = a constant varying from 11 to 19 (15 recommended for normally consolidated clay)

The friction angle for cohesionless soil is related to the cone penetration value empirically as a variation on effective confining stress. The method is shown in Robertson and on Figure 19.5 of Terzaghi[3]. The figure from Terzaghi is included in Attachment C.

The results indicate the native clay cohesion ranges from 600 to 1200 pounds per square foot (psf). For the CCR, friction angle ranges from 30 to 34 degrees and for the imported clayey silt embankment soil the cohesion ranges from 700 to 1950 psf.

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[2] Robertson, P.K. and Campanella, R.G., 1986, "Guidelines for Use, Interpretation and Application of the CPT and CPTU, "UBC, Soil Mechanics Series No. 105, Civil Engineering Department, Vancouver BC, V6T 1W5
[3] Terzaghi, Karl, Ralph Peck and Gholamreza Mesri, "Soil Mechanics in Engineering Practice", Third Edition, John Wiley and Sons, 1996.

3.1.2 Design water surface in impoundments maximum normal pool and maximum pool under design inflow storm

The BGS CCR ponds each have a specific function in the handling of bottom ash and economizer ash process flow or in total suspended solids removal from process and storm water. Fly ash at BGS is handled in a dry silo system and does not go to the CCR ponds.

Based on the 2016 Hazard Potential Analysis conducted by HHS, two of the four ponds are significant hazard potential ponds, and two are low hazard potential ponds. Since the low hazard potential ponds combine with flow from one of the significant hazard potential ponds, the maximum pool elevation is determined from routing a 1,000 year return event 24 hour Type II storm through the ponds[4]

The corresponding normal and maximum water elevations are:

CCR Unit	Normal Pool Water Elevation (feet)	Maximum Pool Elevation (feet)	Embankment Crest Elevation (feet)
BGS Ash Seal Pond	No water	533.4	534
BGS Main Ash Pond	531.5	533.4	534
BGS Economizer Pond	528.0	530.3	548
BGS Upper Ash Pond	528.0	530.3	531

The BGS Economizer Pond is a CCR embankment constructed within the confines of the original BGS Upper Ash Pond and has only a ditch and small ponded area near the center of the 11 acre embankment. Water elevation in the ditch and small Economizer Ash settling pond does not impact the stability of the outer embankment slope. The water elevation in the outer slope is impacted only by the water elevation in the BGS Upper Ash Pond.

3.1.3 Selection of Seismic Design Parameters and Description of Method

The design earthquake ground acceleration is selected from the United States Geologic Survey (USGS) detailed seismic maps based on the latitude and longitude of the BGS.

[4] Inflow Flood Control Plan, Burlington Generating Station, 2016

The peak ground acceleration (PGA) value is selected for a 2% probability of exceedance in 50 years (2500 year return period) as required by §257.53. Since the site soils consist of medium dense to very dense sand from bedrock to elevation 510 and soft to medium stiff clay or loose to very loose CCR above elevation 510, a bedrock PGA of 0.054 g (2500 year return period) was selected using the USGS web site. The ground acceleration for embankment design was determined by multiplying the bedrock acceleration by the weighted amplification factors for PGA using the procedure in the 2009 International Building Code 1613.5.5. The weighting factor calculation based on the know site soil conditions is shown in Appendix E. The Design PGA at the ground surface used for embankment analysis is 0.105 g.

3.1.4 Liquefaction Assessment Method and Parameters

3.1.4.1 Data for Liquefaction Assessment

Certain soils may have zero effective stress (liquefaction) during an earthquake or from static shear of a saturated embankment slope. Soils that will liquefy include loose or very loose uniform fine sand or silt, and soft low-plasticity clay (Plastic Index of less than 12). The liquefaction resistance of a soil is based on its strength and effective confining stress. The strength of the CCR and soil immediately below the CCR may be measured with a Cone Penetrometer Test (ASTM D 5778) or with a standard split spoon test (ASTM D 1586).

The Cone Penetrometer Test was used in 2011 to determine the strength of the embankment soils and to determine the potential for liquefaction during the design earthquake. The Cone Penetrometer test results are coupled with geoprobe push samples to examine the type of soil present and to allow laboratory testing to determine if the soil is a liquefiable soil.

The data indicates that embankment soils and underlying native clay at the BGS Ash Seal Pond, BGS Main Ash Pond and BGS Upper Ash Pond have Plastic Index greater than 20 and will not liquefy in an earthquake or during static shearing. Soils below elevation 510 are sand but are too strong to liquefy during an earthquake. The only soils that could liquefy during an earthquake are the CCR materials in the north embankment of the BGS Economizer Pond. The CCR is saturated in the bottom ten feet of the CCR due to the BGS Upper Ash Pond and the CCR is silt and/or silty sand that is very loose to loose. In reviewing the CPT results, Appendix B, for the north slope of the BGS Economizer Pond, the results from CPT 7 and CPT 8 indicate that the CCR under the clay embankment is denser than the eastern end of the north embankment. The liquefaction assessment is therefore limited to the eastern half of the north embankment where no clay embankment exists over the CCR placed in the BGS Upper Ash Pond.

3.1.4.2 Liquefaction Assessment

The liquefaction assessment using the CPT data is completed using the procedures for simplified assessment of liquefaction potential first proposed by Seed and most recently updated and published by Idriss and Boulanger[5]. The procedure uses the strengths determined by the CPT test adjusted to normalized pressure and for sand fines content to determine the cyclic resistance ratio for the soil at earthquake magnitude 7.5 and at 1 atmosphere pressure. The cyclic resistance ratio is then adjusted for the actual earthquake magnitude of the design event which is 7.7 for a New Madrid Fault source earthquake[6]. The cyclic stress ratio caused by the design surface PGA is then used to determine the actual cyclic stress ratio at 65% of maximum strain at depth in the soil profile. The cyclic resistance ratio is divided by the cyclic stress ratio to determine the factor of safety for liquefaction.

The results for the soil profile on the eastern end of the north embankment of the BGS Economizer Pond are shown in Appendix E. The results indicate that the bottom five

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[5] Idriss I. M. and R. W. Boulanger, "Soil Liquefaction During Earthquakes", EERI MNO-12, 2008.
[6] Elnashai et al, "Impact of Earthquakes on the Central USA", FEMA Report 8-02, Mid-American Earthquake Center, 2002

foot of the CCR just above the native clay will liquefy during the design earthquake of 0.105 g at ground surface.

3.2 BGS Ash Seal Pond

The cross-section analyzed for the BGS Ash Seal Pond is shown on Figure 2. The Section was chosen for its height and proximity to the condenser discharge channel.

The CPT results (CPT-13 and CPT-14) and the laboratory confirmation (SB-8) show the native clay layer is present beneath a coarse grained levee sand deposit and a compacted clay embankment. The compacted clay embankment has cohesion of 700psf and the native clay cohesion of 900 psf. The levee sand has an internal friction angle of 37˚.

3.2.1 Static Safety Factor Assessment Under Maximum Storage Pool Loading - §257.73(e)(1)(i)

The BGS Ash Seal Pond is a zero discharge pond and does not hold water under normal storage pool conditions. The lowest surface elevation of the pond inside of the embankment is elevation 531 and the maximum storage pool is assigned equal to the elevation 526 seven feet above normal pool elevation of the adjacent Mississippi River (elevation 519). Analysis for both a circular and block sliding surface, Appendix F, show a minimum factor of safety of 2.5 for the circular surface.

3.2.2 Static Safety Factor Assessment Under Maximum Surcharge Pool Loading - §257.73(e)(1)(ii)

The BGS Ash Seal Pond is a zero discharge pond that will contain the 1,000 year return period design storm without discharge. Neglecting the likely exfiltration into the coarse levee sand, the full storm is stored in the pond bringing the water elevation to elevation 533.4. Analysis for both a circular and block sliding surface, Appendix F, show a minimum factor of safety of 2.2 for the circular surface.

3.2.3 Seismic Safety Factor Assessment - §257.73(e)(1)(iii)

The BGS Ash Seal Pond was assigned a pseudo-static earthquake coefficient equal to 0.105 g acceleration and a vertical upward component equal to $^2/_3$ of the horizontal component (0.07 g) as recommended by Newmark[7]. Analysis for both a circular and block sliding surface, Appendix F, show a minimum factor of safety of 1.9 for the circular surface.

3.2.4 Post-Liquefaction Safety Factor Assessment - §257.73(e)(1)(iv)

The BGS Ash Seal Pond embankment is constructed of clay that is not susceptible to liquefaction. The underlying native soils are dense coarse sand or native clay neither of which is subject to liquefaction. No post liquefaction slope stability assessment is required.

3.3 BGS Main Ash Pond

The cross-section analyzed for the BGS Main Ash Pond is shown on Figure 2. The Section was chosen for its steeper front slope and proximity to the main ponding area of the BGS Main Ash Pond.

The CPT results (CPT-15 to CPT-18) and the laboratory confirmation (SB-6 and SB-7) show the native clay layer is present beneath a compacted clay embankment. The compacted clay embankment has cohesion of 700 psf and the native clay cohesion of 1200 psf.

3.3.1 Static Safety Factor Assessment Under Maximum Storage Pool Loading - §257.73(e)(1)(i)

The BGS Main Ash Pond receives 1 cubic foot per second of daily average process water flow from the sluicing of bottom ash. The daily flow maintains a storage pool water elevation of 531.5 at the west end of the pond. Analysis of both circular and block sliding surfaces, Appendix F, show a minimum factor of safety of 3.9 for the block slide surface.

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[7] Newmark, N. M. and W. J. Hall, "Earthquake Spectra and Design". EERI Monograph, Earthquake Engineering Research Institute, Berkley California, 1982

3.3.2 Static Safety Factor Assessment Under Maximum Surcharge Pool Loading - §257.73(e)(1)(ii)

The BGS Main Ash Pond will contain the 1000 year return period design storm through a combination of storage in the pond and discharge to the BGS Upper Ash Pond. The maximum surcharge pool loading elevation is 533.4 feet at the peak of the storm.. Analysis for both a circular and block sliding surface, Appendix F, show a minimum factor of safety of 3.8 for the block slide surface.

3.3.3 Seismic Safety Factor Assessment - §257.73(e)(1)(iii)

The BGS Main Ash Pond was assigned a pseudo-static earthquake coefficient equal to 0.105 g acceleration and a vertical upward component equal to $^2/_3$ of the horizontal component (0.07 g) as recommended by Newmark[7]. Analysis for both a circular and block sliding surface, Appendix F, show a minimum factor of safety of 2.6 for the block slide surface.

3.3.4 Post-Liquefaction Safety Factor Assessment - §257.73(e)(1)(iv)

The BGS Main Ash Pond embankment is constructed of clay that is not susceptible to liquefaction. The underlying native clay is also not subject to liquefaction. No post liquefaction slope stability assessment is required.

3.4 BGS Economizer Pond

The BGS Economizer Pond was constructed on top of a portion of the original BGS Upper Ash Pond. The south embankment and the east embankment of the Pond are constructed of imported clay over the clay embankments of the original BGS Upper Ash Pond (CPT 9, 10, 11, and 12 and SB-3). The north and west embankment of the Pond are constructed over CCR that was deposited into the BGS Upper Ash Pond prior to construction of the economizer embankment and are the least stable embankments of the BGS Economizer Pond. Two cross-sections shown on Figure 2 were chosen for analysis on this less stable north embankment.

In 2011 a subsurface investigation was completed, which showed that the eastern 500-feet of the northern embankment of the BGS Economizer Pond was constructed of CCR.

The western part of the north embankment was imported clay compacted on top of CCR. The strength parameters from the CPT results are:

Soil Type	Depth Range (ft)	Cohesion (PSF)	Friction Angle (deg)
Eastern Cross-Section			
CCR cohesionless	0-20	0	34
CCR cohesionless	20-33		32
CCR cohesive (two small layers)	20-33	1,000	0
Native Clay	33-41	600	0
Native Dense Sand	>41	0	30
Western Cross-Section			
Embankment Clay	0-15	1,200	0
CCR	15-25	0	32
Native Clay	25-35	700	0
Native Dense Sand	>40	0	30

3.4.1 Static Safety Factor Assessment Under Maximum Storage Pool Loading - §257.73(e)(1)(i)

The BGS Economizer Pond receives 1.5 cubic foot per second of daily average process water flow from the sluicing of economizer ash and other minor plant process flows. The daily flow discharges through a small 0.4 acre settling pond and ditch to exit the Economizer at the west end discharging to the BGS Upper Ash Pond. The ditch and ponded water have no impact on the north embankment and the static water elevation is the same as the BGS Upper Ash Pond at elevation 528. Analysis of both circular and block sliding surfaces, Appendix F, show a minimum factor of safety of 2.1 western slope and 2.2 eastern slope for the block slide surface.

3.4.2 Static Safety Factor Assessment Under Maximum Surcharge Pool Loading - §257.73(e)(1)(ii)

The BGS Economizer Pond will route the 1000 year return period design storm with virtually no storage. The maximum surcharge pool loading elevation will be the rise in water elevation to 531 feet in the BGS Upper Ash Pond. Analysis for both a circular and block sliding surface, Appendix F, show a minimum factor of safety of 2.1 for the western slope and 2.1 for the eastern slope for the block slide surface.

3.4.3 Seismic Safety Factor Assessment - §257.73(e)(1)(iii)

The BGS Economizer Pond was assigned a pseudo-static earthquake coefficient equal to 0.105 g acceleration and a vertical upward component equal to $^2/_3$ of the horizontal component (0.07 g) as recommended by Newmark[7]. Analysis for both a circular and block sliding surface, Appendix F, show a minimum factor of safety of 1.3 for the western slope and 1.2 for the eastern slope for the block slide surface.

3.4.4 Post-Liquefaction Safety Factor Assessment - §257.73(e)(1)(iv)

The BGS Economizer Pond western north embankment is constructed of clay that is not susceptible to liquefaction and overlies medium dense CCR (equivalent SPT blow count > 10). The eastern embankment is constructed of CCR and overlies a very loose layer of CCR near the base of the Pond just above the native clay. Analysis of liquefaction potential indicates the very loose layer will liquefy during the design earthquake.

Idriss and Boulanger[4] provide empirical data to estimate the post-liquefaction strength of the liquefied layer based on its fines content corrected normalized CPT value. The result is a cohesion of 100 psf as shown in Appendix E. Analysis of the eastern slope using both a circle and block slide mode with the reduced post-liquefaction strength of the CCR layer which liquefied indicates a minimum factor of safety of 1.4 for the block slide.

3.5 BGS Upper Ash Pond

The cross-section analyzed for the BGS Upper Ash Pond is shown on Figure 2. The Section was chosen for its steeper front slope and proximity to the discharge of the BGS Upper Ash Pond.

The CPT results (CPT-20 and CPT-21) and the laboratory confirmation (SB-11 and SB-12) show the native clay layer is present beneath a compacted clay embankment. The compacted clay embankment has cohesion of 1950 psf and the native clay cohesion of 900 psf. Below the native clay is a medium dense sand with a friction angle of 35˚.

3.5.1 Static Safety Factor Assessment Under Maximum Storage Pool Loading - §257.73(e)(1)(i)

The BGS Upper Ash Pond receives 2.5 cubic foot per second of daily average process water flow from the BGS Main Ash Pond and the Economizer Ash Pond. The daily flow maintains a storage pool water elevation of 528.0. Analysis of both circular and block sliding surfaces, Appendix F, show a minimum factor of safety of 3.3 for the block slide surface.

3.5.2 Static Safety Factor Assessment Under Maximum Surcharge Pool Loading - §257.73(e)(1)(ii)

The BGS Upper Ash Pond will contain the 1000 year return period design storm through a combination of storage in the pond and discharge to the Lower Ash Pond. The maximum surcharge pool loading elevation is 530.3 feet at the peak of the storm. Analysis for both a circular and block sliding surface, Appendix F, show a minimum factor of safety of 3.2 for the block slide surface.

3.5.3 Seismic Safety Factor Assessment - §257.73(e)(1)(iii)

The BGS Upper Ash Pond was assigned a pseudo-static earthquake coefficient equal to 0.105 g acceleration and a vertical upward component equal to $^{2}/_{3}$ of the horizontal component (0.07 g) as recommended by Newmark[7]. Analysis for both a circular and block sliding surface, Appendix F, show a minimum factor of safety of 2.4 for the block slide surface.

3.5.4 Post-Liquefaction Safety Factor Assessment - §257.73(e)(1)(iv)

The BGS Main Ash Pond embankment is constructed of clay that is not susceptible to liquefaction. The underlying native clay is also not subject to liquefaction. No post liquefaction slope stability assessment is required.

4 Results Summary

The results of the safety factor assessment indicate that the embankments of all four CCR ponds at BGS meet the requirements of §257.73 (e). The results are summarized as:

Summary
Slope Stability Safety Factors
BGS CCR Units

	Static Stability Normal Water Elevation	Static Stability Flood Water Elevation	Pseudo-Static Earthquake with Normal Water Elevation	Liquefaction Potential	Post-Earthquake Static Stability Normal Water Elevation
Required Safety Factor	1.5	1.4	1.0		1.2
BGS Ash Seal Pond	2.5	2.2	1.9	no	
BGS Main Ash Pond	3.9	3.8	2.6	no	
BGS Economizer Pond East Slope	2.2	2.1	1.2	yes	1.4
BGS Economizer Pond West Slope	2.1	2.1	1.3	no	
BGS Upper Ash Pond	3.3	3.2	2.4	no	

5 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

To meet the requirements of 40 CFR 257.73(e)(2), I Mark W. Loerop hereby certify that I am a licensed professional engineer in the State of Iowa; and that, to the best of my knowledge, all information contained in this document is correct and the document was prepared in compliance with all applicable requirements in 40 CFR 257.73(b) and 40 CFR 257.73(e).

LICENSED PROFESSIONAL ENGINEER
MARK W. LOEROP
22197
IOWA

By: [signature]

Name: Mark Loerop

Date: 8 - 25 - 2016

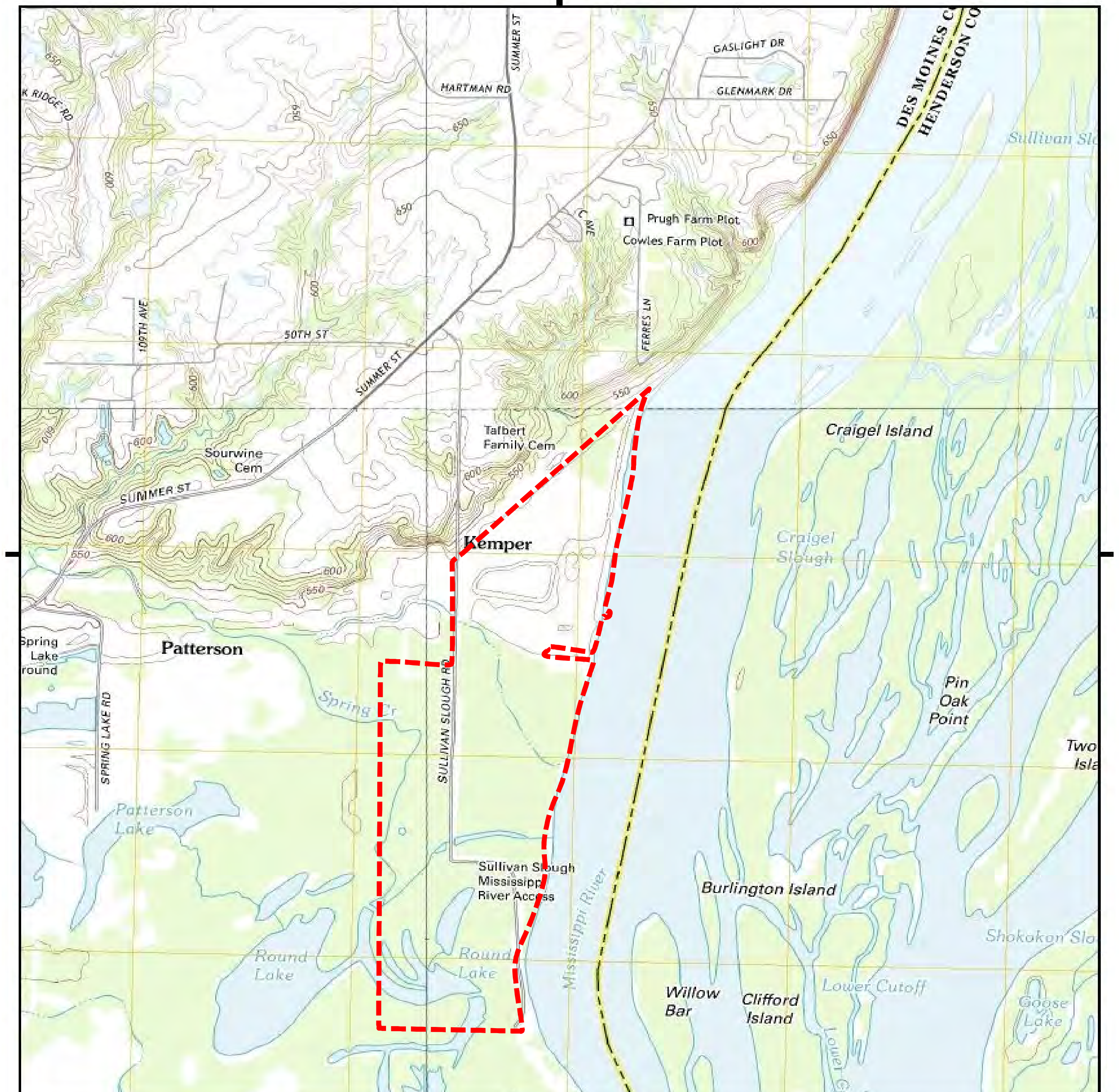
FIGURES

Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

Safety Factor Assessment

Historical Topo Map

2012, 2013



This report includes information from the following map sheet(s).

Miles 0.25 0.5 1 1.5

NW N NE W E SW S SE

TP, Lomax, 2012, 7.5-minute

NE, Burlington, 2013, 7.5-minute

SW, Dallas City, 2012, 7.5-minute

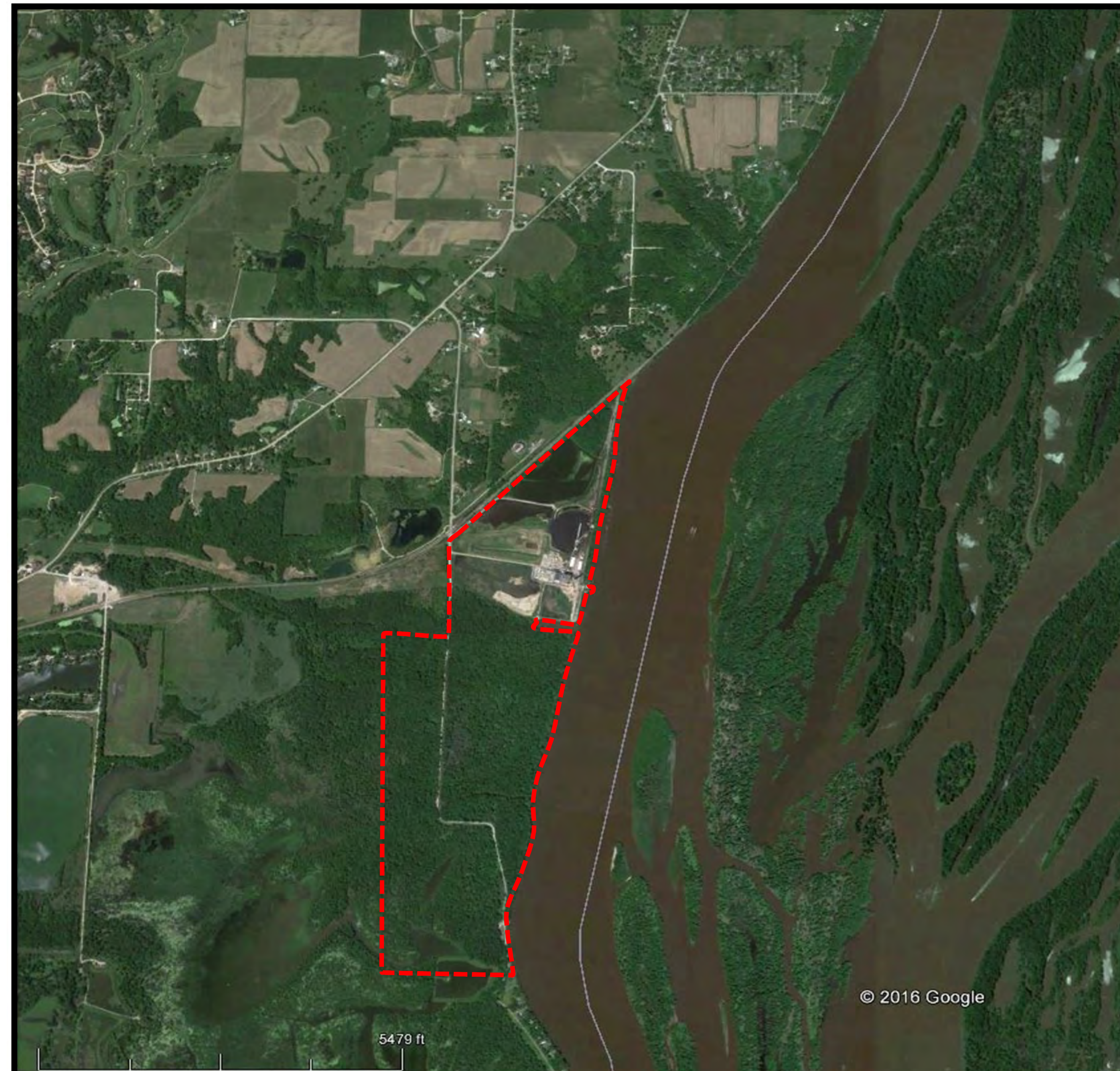
NW, West Burlington, 2013, 7.5-minute

SITE NAME: Burlington Generating Station
ADDRESS: 4282 Sullivan Slough Road
Burlington, IA 52601
CLIENT: Environmental Site Assessors

N

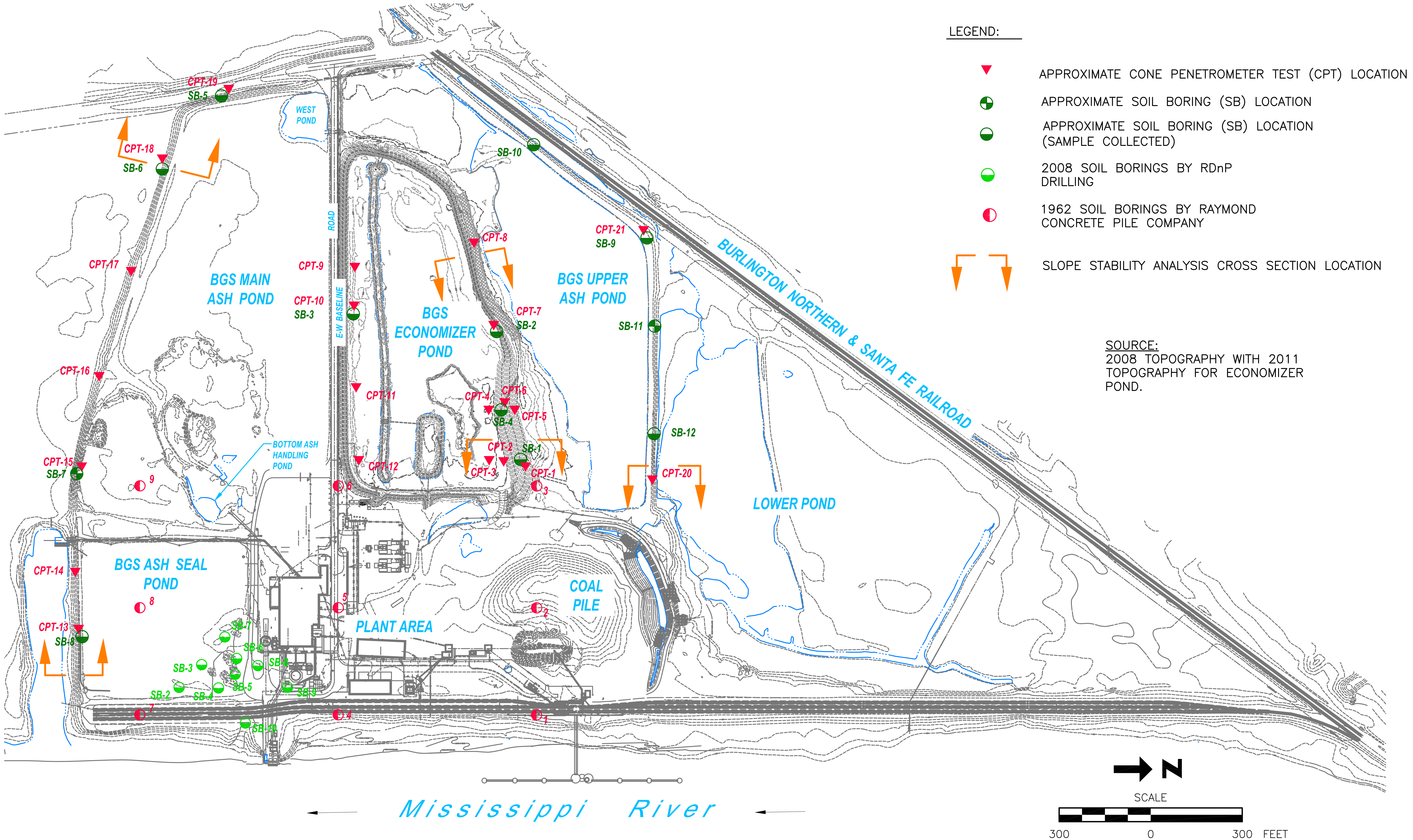
4555570 - 3 page 4

Historical Aerial Photo 6/12/2014



Approximate Property Boundary

HARD HAT SERVICES™ Engineering, Construction and Management Solutions	Site Location Burlington Generating Station Intersate Power and Light Company	Drawing Figure 1 Date 5/25/2016



NOTICE	REV	DATE	BY	DESCRIPTION		
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SCALE: AS SHOWN — DATE: 5–13–16
DRAWN BY: JFD — CHECKED BY: TJH — APPROVED BY: MWL

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

CLIENT / LOCATION
ALLIANT ENERGY
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

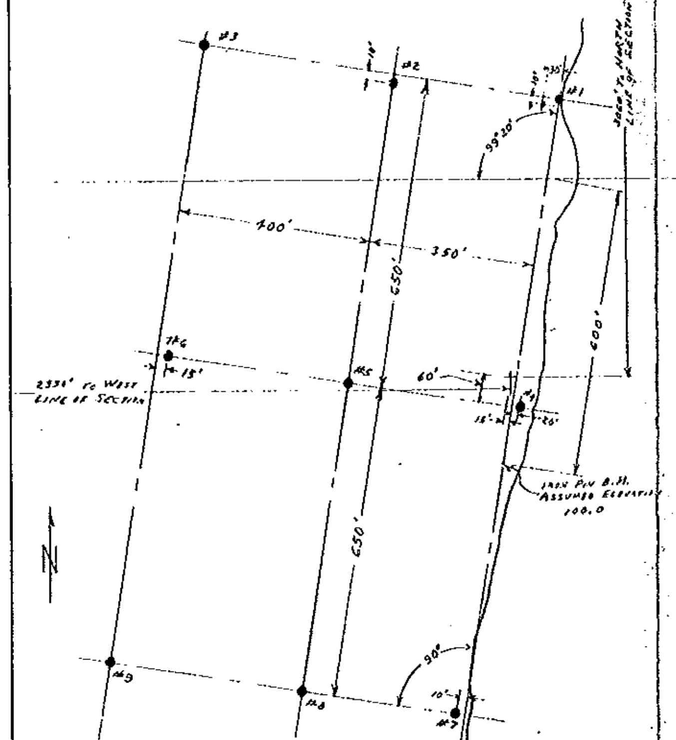
DRAWING DESCRIPTION
SOIL BORINGS, CPT, AND SLOPE STABILITY CROSS SECTION LOCATIONS

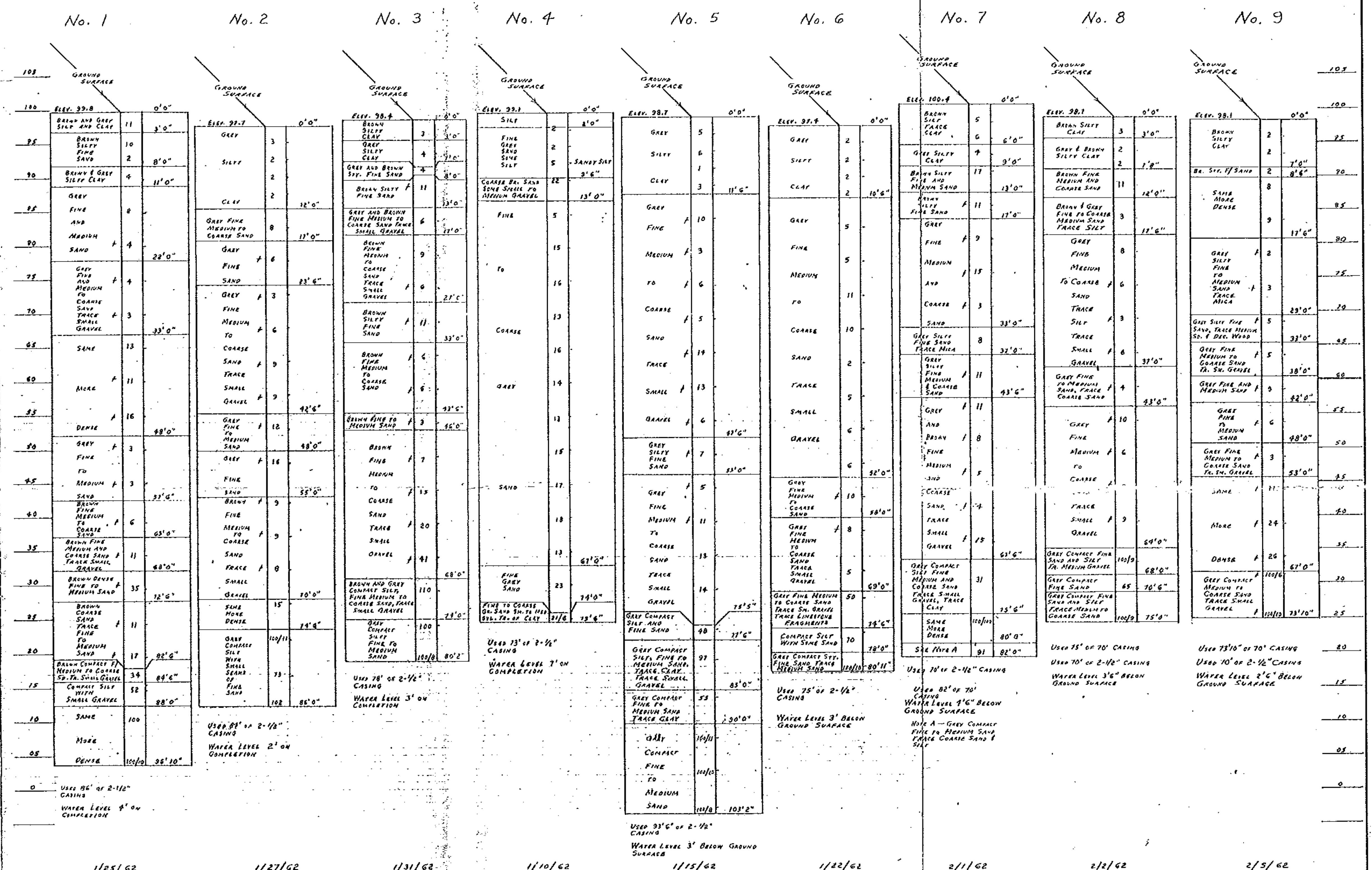
JOB 154.018.012.001
SHT. FIGURE 2
DWG. 154.018.012.001–D2

APPENDIX A – Deep Soil Borings

Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

Safety Factor Assessment





Figures in Right Hand Column Shown as Fractions — Numerator – No. of Blows / Denominator – Penetration in Inches

f Indicates Wash Sample Recovered

Classifications are made by visual inspection. Figures in right hand column indicate number of blows required to drive 2" O.D. sampling pipe one foot, using 140-lb. weight falling 30 inches.

References:
See D-461 For Boring Locations.
Test Boring Report - February 13, 1962, by Raymond Concrete Pile Company, Soil Division, Job No. C8-948-KC Sheets 1 through 4.

IOWA SOUTHERN UTILITIES CO. CENTERVILLE, IOWA	
Proposed Burlington Plant Site Test Boring Reports	
Scale 1" = 8' Vertical	Date 3-15-62
Sketch DWN	TRCD L.L. Achko
D-484	Approved

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-2**
LOGGED BY LES
PAGE No. 1 of 2

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.13
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/11/2008 FINISH 12/12/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	2	3	4	4	14.0		0.75	4'3"	529.88	CL	Black and brown mottled SILTY CLAY, little fine to medium sand, medium plasticity, medium stiff, wet
5	SS-2	4.0	6.0	1	6	5	3	17.0					ML	Grey SILT, trace fine sand, medium dense, moist
	SS-3	6.0	8.0	1	8	15	7	17.5						medium dense
	SS-4	8.0	10.0	1	6	50/5		18.0						very dense
10														
	SS-5	13.0	15.0	1	1	1	1	13.0	49	0.75	13'5"	520.71		
15													CH	Dark brown and black mottled CLAY, trace silt, high plasticity, medium stiff, wet
	SS-6	18.0	20.0	2	2	3	3	15.0	48	0.25 0.50				soft (LL=52, PI=27)
20														
	SS-7	23.0	25.0	4	5	7	12	20.0			23'6"	510.63		
25													SP	Brown fine to medium SAND, medium dense, wet
	SS-8	28.0	30.0	3	12	17	18	9.0						brownish-grey
30														
	SS-9	33.0	35.0	8	10	11	12	11.5						
35														
	SS-10	38.0	40.0	7	7	10	12	10.0						some coarse sand and wood pieces
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-2.XLS

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-2**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.13
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/11/2008 FINISH 12/12/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
													SP	Brownish-grey fine to medium sand, some coarse sand, medium dense, wet (cont.)
	SS-11	43.0	45.0	3	6	12	14	15.5						2" of black silt at 44'1"
45														
											46'6"	487.63	SW	Brownish-grey fine to coarse SAND, medium dense, wet
	SS-12	48.0	50.0	6	7	8	12	16.0						
50														
	SS-13	53.0	55.0	10	11	12	19	21.0						
55														
	SS-14	58.0	60.0	15	22	32	42	24.0						medium to coarse sand, trace fine sand and fine gravel, very dense
60											60'	474.13		EOB 60' - Sand was causing hole to collapse and would have needed to be cased to 60' to continue.
65														
70														
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-2.XLS

BORING LOG

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

PROJECT No. 154.002.008.001
BORING No. BH-B-1 **(BH-3)**
LOGGED BY LES
PAGE No. 1 of 2

PROJECT NAME Alliant Energy - Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
DRILLER RDnP Drilling - Chris
DATE: START 7/15/2008 FINISH 7/21/2008

DEPTH	SAMPLE No.	INTERVAL FROM	INTERVAL TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	USCS SOIL TYPE	SOIL DESCRIPTION
	SS-1	0.0	2.0	5	10	10	12	12	23				Brown and black silty clay FILL, medium dense, dry
	SS-2	2.0	4.0	10	11	11	15	9.5		2.0			Coarse sand and fine gravel FILL, trace grey fines, medium dense, dry
5	SS-3	4.0	6.0	5	10	2	2	10	14	4.0		FILL	some silt
	SS-4	6.0	8.0	1	10	16	12	22		6.0			Grey-black sand and gravel FILL with silt, medium dense wet.
	SS-5	8.0	10.0	6	10	22	32	24	24		10.0		
10	SS-6	10.0	12.0	3	8	3	2	14					Grey sandy SILT, trace coarse sand, loose, saturated
	SS-7	12.0	14.0	1	0	1	0	18	50				Grey SILT, little fine sand, very loose, saturated
15	SS-8	14.0	16.0	Rod Weight				17				ML	
20	SS-9	18.0	20.0	1	1	1	1	16	33				trace low plasticity clay, trace fine sand
											22'6"		Dark grey SILTY CLAY, trace fine sand, medium to high plasticity, soft, wet
25	SS-10	23.0	25.0	1	2	2	1	18				CL	
											26.5		Grey fine to medium grained SAND, trace coarse sand, very loose, saturated
30	SS-11	28.0	30.0	1	0	0	0	3	18				
35	SS-12	33.0	35.0	5	8	12	14	11				SP	medium dense
40	SS-13	38.0	40.0	8	10	11	12	11	13				

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-3.XLS

BORING LOG

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

PROJECT No. 154.002.008.001
BORING No. BH-B-1 **(BH-3)**
LOGGED BY LES
PAGE No. 2 of 2

PROJECT NAME Alliant Energy - Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
DRILLER RDnP Drilling - Chris DATE: START 7/15/2008 FINISH 7/21/2008

DEPTH	SAMPLE No.	INTERVAL FROM	INTERVAL TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	USCS SOIL TYPE	SOIL DESCRIPTION
													Grey fine to medium SAND, trace coarse sand, medium dense, saturated
45	SS-14	43.0	45.0	5	10	14	22	11					
50	SS-15	48.0	50.0	9	14	16	16	12	15				
55	SS-16	53.0	55.0	8	12	14	15	11				SP	
60	SS-17	58.0	60.0	10	11	18	24	10	13				several pieces of coarse grained gravel at 58.5'
65	SS-18	63.0	65.0	15	24	26	36	10					dense
											66.5		Grey fine to coarse SAND and fine grained gravel, very dense, saturated
70	SS-19	68.0	70.0	32	32	38		12	9			SW	
75	SS-20	73.0	75.0	32	75/3			4					
											76.5	GP	Fine GRAVEL with fine to coarse sand, very dense, saturated
80	SS-21	78.0	80.0	50	100/3			4	8		79.5		Spoon bounced at 79.5'
													EOB at 80'

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-3.XLS

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-4**
LOGGED BY LES

PROJECT NAME: Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION: Burlington, Iowa
SURFACE ELEVATION: 534.43
DRILLER: RDnP Drilling - Kris Norwick
DATE: START 12/2/2008 FINISH 12/3/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNTS 0"–6"	BLOW COUNTS 6"–12"	BLOW COUNTS 12"–18"	BLOW COUNTS 18"–24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	3	4	5	15	16.0					FILL	Black and brown silty clay FILL, some fine sand, dry
5	SS-2	4.0	6.0	9	8	11	12	17.0						Black and brown fine to coarse sand and fine gravel FILL, trace fines, wet
	SS-3	6.0	8.0	10	5	12	15	20.0			6'6"	527.93	ML	Grey SILT, little fine sand, medium dense, saturated
	SS-4	8.0	10.0	2	2	3	20	24.0						loose 4" fine sand seam at 9'6"
10														
											11'6"	522.93	CL	Grey SILTY-CLAY, trace fine sand, medium plasticity, soft, moist to wet
	SS-5	13.0	15.0	2	2	3	4	14.0	50	2.00				
15														
	SS-6	18.0	20.0	7	9	8	11	15.0			18'4"	516.10	SP	Grey-brown fine to coarse SAND, medium dense, wet
20														
	SS-7	23.0	25.0	10	11	15	15	12.0	18					
25														
	SS-8	28.0	30.0	6	10	12	14	11.0						
30														
	SS-9	33.0	35.0	6	7	9	11	11.0	19					trace fine gravel
35														
											36'6"	497.93	SW	Brown fine to coarse SAND, little fine gravel, trace silt, medium dense, wet
	SS-10	38.0	40.0	7	9	7	10	10.0						
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-4.XLS

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-4**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.43
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/2/2008 FINISH 12/3/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														(cont.) Brown fine to coarse SAND, little fine gravel, medium dense, wet
	SS-11	43.0	45.0	5	6	6	8	11.0	14					
45														
	SS-12	48.0	50.0	12	12	16	19	10.0						
50														
	SS-13	53.0	55.0	8	9	11	14	12.0	13				SW	
55														
	SS-14	58.0	60.0	10	8	10	13	12.0						
60														
	SS-15	63.0	65.0	18	21	32	50/5	16.0	11					very dense
65														
											64'6"	469.93		Grey silty CLAY, trace fine sand, medium plasticity, hard, wet
	SS-16	68.0	70.0	21	32	42	44	24.0		+4.5			CL	
70														
	SS-17	73.0	75.0	10	17	22	23	20.0	25					
75											75'	459.43		EOB 75'
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-4.XLS

HARD HAT SERVICES ™
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BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-5**
LOGGED BY LES
PAGE No. 1 of 2

PROJECT NAME: Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION: Burlington, Iowa
SURFACE ELEVATION: 534.71
DRILLER: RDnP Drilling - Kris Norwick
DATE: START 12/4/2008 FINISH 12/5/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	6"-12"	12"-18"	18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	15	19	22	23	12.0						Black and brown sand and gravel FILL, some fines, wet
5	SS-2	4.0	6.0	10	19	34	50/3	16.0					FILL	
	SS-3	6.0	8.0	32	32	22	8	18.0						Brown-grey silt with sand FILL
	SS-4	8.0	10.0	9	12	23	14	20.0						6" brown-red fine to coarse sand FILL
10	SS-5	10.0	12.0	1	2	4	1	24.0			10'	524.71	ML	Grey SILT, little fine sand, loose, wet
	SS-6	13.0	15.0	1	1	2	3	21.0	36		13'	521.71		Mottled green, black, and light grey SILTY CLAY, little fine sand, trace silt and wood pieces, medium stiff, wet
15														
	SS-7	18.0	20.0	2	2	3	3	13.0	34	1.00			CL	
20														
	SS-8	23.0	25.0	5	7	7	9	14.5			23'2"	511.54		Black and brown fine to medium SAND, trace coarse sand, medium dense, wet 23'7" grey
25														
	SS-9	28.0	30.0	3	4	6	7	13.0	19					
30														
													SP	
	SS-10	33.0	35.0	7	7	9	11	12.0						
35														
														5" fine sand seam
	SS-11	38.0	40.0	7	10	11	14	14.0	22					2" coarse sand and fine gravel seam
40														

Drilled with Dietrich -120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES ™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-5**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.71
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/4/2008 FINISH 12/5/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	6"-12"	12"-18"	18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														(cont.) Grey fine to medium SAND, trace coarse sand, wet
	SS-12	43.0	45.0	12	15	22	26	13.5						dense
45														
	SS-13	48.0	50.0	10	12	12	15	12	17				SP	medium dense
50														
	SS-14	53.0	55.0	5	15	21	15	13						dense, 53'6" - 1" gravel piece
55														medium dense
	SS-15	58.0	60.0	6	8	11	15	10	12		58'7"	476.13		Grey fine to coarse SAND, some fine gravel, very dense
60														
	SS-16	63.0	65.0	50/0				0					SW	
65														(rig was grinding heavily to get from 65' to 68')
	SS-17	68.0	70.0	50/4				4			70'	464.71		EOB 70'
70														
75														
80														

Drilled with Dietrich -120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-5.XLS

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-6**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.33
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/4/2008 FINISH 12/5/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	10	11	15	17	17.0						Brown silty sand FILL, trace medium sand, medium dense
5	SS-2	4.0	6.0	1	3	5	11	13.0					FILL	
	SS-3	6.0	8.0	50/5				7.5						(possibly gravel inhibiting sampling)
	SS-4	8.0	10.0	41	50/3			5.5						
10											10'	524.33		
	SS-5	10.0	12.0	3	2	1	4	20.0	49					Brownish-grey SILT, trace fine sand, very loose, saturated
	SS-6	13.0	15.0	3	4	4	5	24.0	53				ML	loose
15														
											16'6"	517.83		Brownish-grey SILTY CLAY, trace fine sand, soft, wet
	SS-7	18.0	20.0	1	1	1	2	17.0	49	0.50				
20													CL	
	SS-8	23.0	25.0	1	3	4	5	16.0			24'	510.33		Brown fine to medium SAND, trace coarse sand, medium dense, wet
25														
	SS-9	28.0	30.0	6	7	9	11	15.5	18					
30													SP	
	SS-10	33.0	35.0	10	11	14	14	12.0						
35														
											36'6"	497.83		Brown fine to coarse SAND, little fine gravel, medium dense, wet
	SS-11	38.0	40.0	6	8	9	12	12.5	9				SW	
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-6.XLS

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-6**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.33
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/4/2008 FINISH 12/5/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	6"-12"	12"-18"	18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
													SW	Brown fine to coarse SAND, little fine gravel, medium dense, wet (cont.)
											42'6"	491.83		Brown fine to medium sand, trace fine sand, medium dense to dense, wet (cont.)
	SS-12	43.0	45.0	8	10	14	17	12.0						
45														
	SS-13	48.0	50.0	8	9	12	14	12.0	14					little coarse sand
50													SP	
	SS-14	53.0	55.0	10	17	17	15	12.5						
55														
	SS-15	58.0	60.0	10	12	14	14	10.0	14					
60														
											62' 6"	472.00		Grey SILTY CLAY, little fine to medium sand, medium plasticity, hard, wet 1" fine to medium sand seam at 63'6" 1" gravel piece at 6'8"
	SS-16	63.0	65.0	17	31	36	42	22.0	14	4.5+ 4.5+				
65													CL	
	SS-17	68.0	70.0	21	50/3			9.0		4.5+				
70											70'	464.33		EOB 70'
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-7**
LOGGED BY LES
PAGE No. 1 of 2

PROJECT NAME: Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION: Burlington, Iowa
SURFACE ELEVATION: 536.51
DRILLER: RDnP Drilling - Kris Norwick
DATE: START 12/5/2008 FINISH 12/8/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	6"-12"	12"-18"	18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	6	7	10	12	22.5		1.00 0.75			FILL	Black sand, gravel, and silt FILL 6" alternating brown and black fine sand and silt at 3' 6"grey clay, medium stiff, moist at 4'
5	SS-2	4.0	6.0	1	3	10	14	15.0						
	SS-3	6.0	8.0	10	31	21	33	18.0			6'	530.51	ML	Dark grey SILT, some fine sand, very dense, wet
	SS-4	8.0	10.0	15	21	18	15	17.0						
10	SS-5	10.0	12.0	10	22	32	44	21.0						trace fine sand
	SS-6	13.0	15.0	3	4	1	5	23.0	67					loose
15														
											16'6"	520.01	CL	Grey SILTY CLAY, trace fine sand, very soft, wet
	SS-7	18.0	20.0	1	2	1	2	24.0						
20														
											23'6"	513.01	SP-SC	Grey fine to medium SAND with clay, loose, wet
	SS-8	23.0	25.0	1	2	4	12	16.0	19					
25														
											26'6"	510.01	SP	Grey fine to medium SAND, medium dense, wet
	SS-9	28.0	30.0	2	5	8	8	18.0						
30														
	SS-10	33.0	35.0	8	14	16	15	12.0	17					trace coarse sand
35														
	SS-11	38.0	40.0	8	14	10	8	12.0						medium dense
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-7.XLS

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-7**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 536.51
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/5/2008 FINISH 12/8/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Grey fine to medium SAND, trace coarse sand medium dense, wet
	SS-12	43.0	45.0	5	8	10	11	12.0	15					
45														
	SS-13	48.0	50.0	8	10	15	18	14.0					SP	
50														
	SS-14	53.0	55.0	10	12	15	16	10.0	15					
55														
											56'6"	480.01		Brown fine to coarse SAND, trace fine gravel, medium dense, wet
	SS-15	58.0	60.0	8	11	15	17	24.0						
60													SW	
	SS-16	63.0	65.0	18	23	50/4		10.0	7					very dense
65											65'	471.51		EOB 65'
70														
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-8**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.72
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/15/2008 FINISH 12/17/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	6"-12"	12"-18"	18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	8	12	10	12	18.0						Brown and grey mottled silty clay FILL, little fine to coarse sand, medium dense, frozen
5	SS-2	4.0	6.0	3	4	6	6	16.0		1.75			FILL	
	SS-3	6.0	8.0	3	5	7	10	10.0						fine gravel pieces mixed in clay
	SS-4	8.0	10.0	3	4	6	9	15.0	17	2.50				
10	SS-5	10.0	12.0	4	5	7	4	14.0	23	3.00	10'6"	524.22		Grey SILT, trace fine sand, medium dense to loose, wet
	SS-6	13.0	15.0	2	3	3	3	8.0	26				ML	alternating silt and brown silty clay, stiff
15														
											16'6	518.22		Grey SILTY CLAY, medium plasticity, medium stiff, mois to wet (LL=46, PI=24)
	SS-7	18.0	20.0	1	2	3	2	10.0	34	1.25				
20													CL	
											23'3"	511.47		Brown fine to medium SAND, loose, wet
	SS-8	23.0	25.0	5	6	7	7	12.0						
25														
	SS-9	28.0	30.0	2	5	4	5	24.0	20					
30														
													SP	
	SS-10	33.0	35.0	2	3	4	5	12.0						trace coarse sand
35														
	SS-11	38.0	40.0	4	5	5	7	11.5	12					
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-8.XLS

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-8**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION 534.72
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/15/2008 FINISH 12/17/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Brown fine to medium SAND, trace coarse sand, medium dense, wet (cont.)
	SS-12	43.0	45.0	9	10	11	15	11.0						
45													SP	
	SS-13	48.0	50.0	14	17	9	7	13.0	16					
50														
											49'6"	485.22		Brown fine to coarse SAND, trace fine gravel, medium dense, wet
	SS-14	53.0	55.0	4	8	7	6	13.0						
55														
	SS-15	58.0	60.0	8	15	19	22	15.0	8					dense
60													SW	
	SS-16	63.0	65.0	5	15	24	26	17.0						little fine gravel
65														
											66'6"	468.22		Grey sandy SILTY CLAY, hard, moist to wet
	SS-17	68.0	70.0	48	50/4			13.0	14				CL	
70											70'	464.72		EOB 70'
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-8.XLS

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-9**
LOGGED BY LES

PROJECT NAME: Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION: Burlington, Iowa
SURFACE ELEVATION: 534.67
DRILLER: RDnP Drilling - Kris Norwick
DATE: START 12/17/2008 FINISH 12/18/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	6"-12"	12"-18"	18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	3	4	2	2	14.0		2.50				Grey and brown mottled silty clay FILL, some fine to medium sand, very stiff, moist
5	SS-2	4.0	6.0	3	4	6	5	17.0		4.00			FILL	
	SS-3	6.0	8.0	4	5	5	8	17.0		2.50				Alternating grey, brown, and orange clay and silt
	SS-4	8.0	10.0	4	5	10	10	17.0		2.00	8'11"	525.75		
10	SS-5	10.0	12.0	5	7	9	12	16.0		4.00			CL	Grey SILTY CLAY, trace fine sand, medium plasticity, very stiff, moist
	SS-6	13.0	15.0	3	4	6	6	21.0			13'	521.67		Dark grey CLAY, high plasticity, stiff, wet
15														
	SS-7	18.0	20.0	3	3	4	5	21.0	51	1.00				(LL=64, PI=34)
20													CH	
	SS-8	23.0	25.0	5	6	8	9	0.0						
25														(hole is taking a lot of water)
											24'6"	510.17		Grey fine to medium SAND, medium dense, wet
	SS-9	28.0	30.0	8	10	12	14	10.0	25					
30														
	SS-10	33.0	35.0	8	15	19	22	16.0					SP	trace coarse sand, dense
35														
	SS-11	38.0	40.0	10	16	17	19	11.0	18					
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-9.XLS

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-9**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa
SURFACE ELEVATION
DRILLER RDnP Drilling - Kris Norwick
DATE: START 12/17/2008 FINISH 12/18/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Grey fine to medium SAND, trace coarse sand, dense, wet
	SS-12	43.0	45.0	10	17	24	29	8.0						trace fine gravel
45														
	SS-13	48.0	50.0	8	16	20	21	12.0	17				SP	
50														
	SS-14	53.0	55.0	9	11	15	19	13.0						
55														
											56'6"	478.17		Grey-brown fine to coarse SAND, trace fine gravel, dense, wet
	SS-15	58.0	60.0	10	12	18	17	16.0	17					
60													SW	
	SS-16	63.0	65.0	12	15	24	26	15.0						dense
65														
											66'6"	468.17		Grey CLAY, little fine to medium sand, medium plasticity, hard, moist to wet
	SS-17	68.0	70.0	37	50/4			10.0					CL	
70											70'	464.67		EOB 70'
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-9.XLS

HARD HAT SERVICES™
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BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-10**
LOGGED BY LES

PROJECT NAME Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION Burlington, Iowa SURFACE ELEVATION 531.92
DRILLER RDnP Drilling - Kris Norwick DATE: START 12/12/2008 FINISH 12/15/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Frozen ground
	SS-1	2.0	4.0	4	5	5	4	13.0	17	2.00				Grey and brown mottled SILTY CLAY, trace fine sand, medium plasticity, stiff, moist
5	SS-2	4.0	6.0	3	4	5	6	15.0	15	2.50				little fine to coarse sand, very stiff
	SS-3	6.0	8.0	4	4	5	6	15.0	13	2.50			CL	
	SS-4	8.0	10.0	3	6	8	8	15.0	24	2.50 1.50				Brown, silt content increasing, thin brown silt seams
10														
											13'	518.92		
	SS-5	13.0	15.0	1	2	3	4	15.0		0.75 1.00				Dark grey CLAY, high plasticity, medium stiff, wet
15														
	SS-6	18.0	20.0	4	6	5	7	13.5		1.25				stiff
20													CH	
	SS-7	23.0	25.0	3	4	5	5	6.0		1.00				
25														
	SS-8	28.0	30.0	8	9	11	12	0.0			29'	502.92		Grey-brown fine to medium SAND, medium dense, wet
30														
	SS-9	33.0	35.0	6	8	5	5	10.0						
35														trace coarse sand
	SS-10	38.0	40.0	8	9	11	12	11.0						
40														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

HARD HAT SERVICES™
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BORING LOG

PROJECT No. 154.002.008.001
BORING No. **BH-10**
LOGGED BY LES
PAGE No. 2 of 2

PROJECT NAME: Alliant Energy - December 2008 Baghouse Geotechnical Investigation
BORING LOCATION: Burlington, Iowa
SURFACE ELEVATION: 531.92
DRILLER: RDnP Drilling - Kris Norwick
DATE: START 12/12/2008 FINISH 12/15/2008

DEPTH	SAMPLE No.	INTERVAL (ft) FROM	INTERVAL (ft) TO	BLOW COUNT 0"-6"	BLOW COUNT 6"-12"	BLOW COUNT 12"-18"	BLOW COUNT 18"-24"	REC (in)	WC (%)	qu (TSF)	CONTACT DEPTH	ELEV. (MSL)	USCS SOIL TYPE	SOIL DESCRIPTION
														Grey-brown fine to medium SAND, trace coarse sand, medium dense, wet (cont.)
	SS-11	43.0	45.0	3	6	9	15	15.0						
45														dense
	SS-12	48.0	50.0	8	15	21	30	15.0						
50													SP	
	SS-13	53.0	55.0	50/0				0.0						(spoon bouncing, possibly on a cobble or boulder)
55														trace fine gravel
	SS-14	58.0	60.0	14	17	17	15	16.0						
60														
	SS-15	63.0	65.0	50/1				0.0			64'	467.92		Grey CLAY, little fine sand, hard, moist to wet
65													CL	
	SS-16	68.0	70.0	32	50/3			10.0		4.5+				(spoon bouncing)
70											70'	461.92		EOB 70'
75														
80														

Drilled with Dietrich-120
Method: auger and mud rotary
Hole was backfilled with bentonite slurry

BH-10.XLS

APPENDIX B – Geoprobe Soil Borings on CCR Embankments

Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

Safety Factor Assessment

Boring Log Legend

Sample
No: (Number) Soil samples are numbered consecutively from the ground surface. Core samples are numbered consecutively from the first core run.

Type: A= Auger Cuttings CR= Core Run MS= Modified Spoon PB= Pitcher Barrel
PT= Piston Tube ST= Shelby Tube SS= Split Spoon (2" O.D.) WC= Wash Cuttings

Interval: The depth of sampling interval in feet below ground surface

Blow Count
The number of blows required to drive a 2-inch O.D. split-spoon sampler with a 140 pound hammer falling 30-inches. When appropriate, the sampler is driven 18 inches and blow counts are reported for each 6-inch interval. The sum of blow counts for the last two 6-inch intervals is designated as the standard penetration resistance (N) expressed as blows per foot.

Recovery in Inches
The length of sample recovered by the sampling device.

U.S.C.S. Soil Type
The Unified Soil Classification System symbol for recovered soil samples determined by visual examination or laboratory tests. Refer to ASTM D2487-69 for a detailed description of procedure and symbols. Underlined symbols denote classifications based on laboratory tests (i.e. ML), all others are based on visual classification only.

Percent Moisture
Natural moisture content of sample expressed as percent of dry weight.

q_u TSF
Unconfined compressive strength in tons per square foot obtained by hand penetrometer. Laboratory compression test values are indicated by underlining.

Contact Depth
The contact depth between soil layers is interpreted from significant changes in recovered samples and observations during drilling. Actual changes between soil layers often occur gradually and the contact depths shown on the boring logs should be considered as approximate.

Soil Description and Remarks
Soil descriptions include consistency or density, color, predominant soil types and modifying constituents.

Cohesive Soils			Cohesionless Soils	
Consistency	q_u (TSF)	Blows/ft.	Density	Blows/ft.
Very Soft	less than 0.25	0-1	Very Loose	4 or less
Soft	0.25 to 0.50	2-4	Loose	5 to 10
Medium Stiff	0.50 to 1.00	5-8	Medium Dense	11 to 30
Stiff	1.00 to 2.00	9-15	Dense	30 to 50
Very Stiff	2.00 to 4.00	15-30	Very Dense	Over 50
Hard	more than 4.00	Over 30		

Particle Size Description

Boulder =	Larger than 12 inches
Cobble =	3 to 12 inches
Gravel =	0.187 to 3 inches
Sand =	0.074 to 4.76 mm
Silt and Clay =	smaller than 0.074 mm

Definition of Terms

Trace =	5 to 12 percent by weight
Some =	12 to 30 percent by weight
And =	Approximately equal fractions
( ) =	Driller's observation

Piezo.
(Piezometer) Screened interval of the piezometer installation is denoted by cross-hatching.

General Note
The boring log and related information depicted subsurface conditions only at the specified locations and date indicated. Soil conditions and water levels at other locations may differ from conditions occurring at these boring locations. Also the passage of time may result in a change in the conditions at these boring locations.

Soil Test Boring Refusal
Defined as any material causing a blow count greater that 50 blows/6 inches. Such material may include bedrock, "floating" rock slabs, boulders, dense gravel seams, hard pan clay, or cemented soils. Refusal is usually indicated in fractional notation showing number of blows as the numerator and inches of penetration as the denominator.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

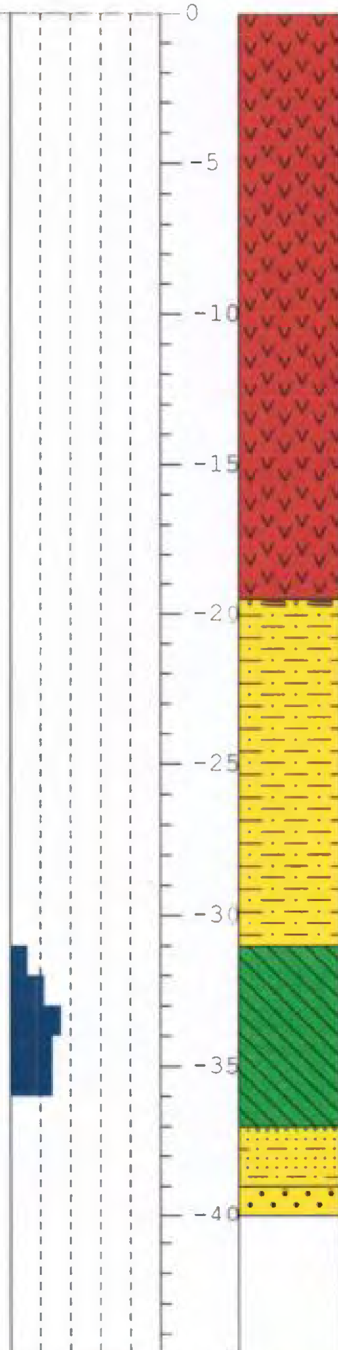
PROJECT: Burlington, IA

COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*

BORING NO.: *SB1 (CPT1)*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-11-11*
DATE FINISHED: *05-11-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)	CONSISTENCY vs. DEPTH	DEPTH IN FEET	PROFILE	DESCRIPTION
						0		ASH; brown; poorly graded; fine grained; moist. (Fill)
	SP1	2.5'/5'						
						-5		
	SP2	5'/5'						
						-10		
	SP3	5'/5'						
						-15		@ 14' grades dark gray to black.
	SP4	5'/5'						
∇						-20		Clayey SILT; black to gray; non-plastic to low plasticity; moist to wet; some organic matter. (OL) @ too soft for pocket penn from 19.5' to 31', no hammer required to push sampler.
	SP5	0'/5'						
						-25		
	SP6	5'/5'						
						-30		
	SP7	1.5'/5'		2.75 2.75 3.25 3.75 1.5				CLAY; gray to black; high plasticity; soft to firm; moist; trace organic. (OH)
						-35		
	SP8	5'/5'						Sandy SILT; gray; non-plastic; wet. (ML)
						-40		SAND; gray; well graded; fine to coarse grained; rounded to sub-rounded; wet. (SW)
								Bottom of Boring @ 40' Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-11-11.
						-45		



CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

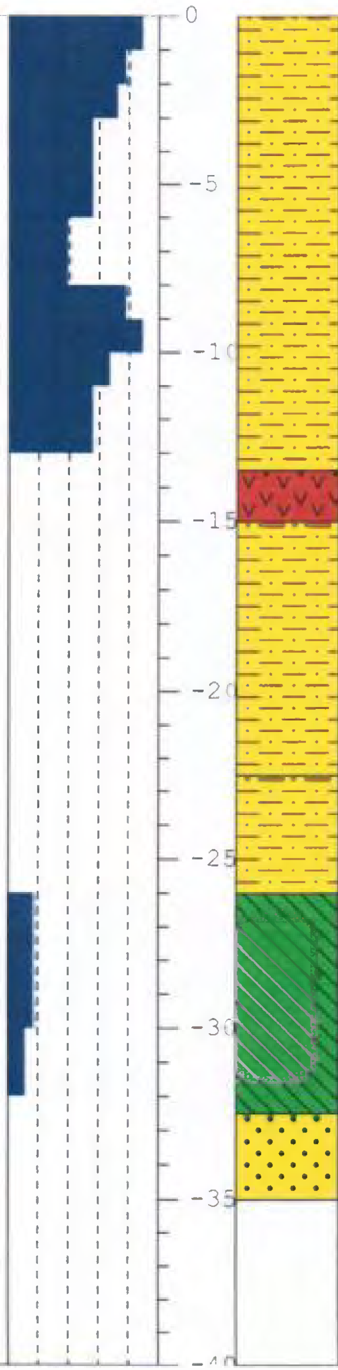
PROJECT: Burlington, IA

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SB2 (CPT7)*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-11-11*
DATE FINISHED: *05-11-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	5'/5'		4.0, 3.5, 3.25, 2.5, 2.5
	SP2	5'/5'		2.5, 1.75, 1.75, 3.5, 4.0
	SP3	5'/5'		3.0, 2.5, 2.5
	SP4	4'/5'		
▽	SP5	4'/5'		
	SP6	5'/5'		0.75, 0.75, 0.75, 0.75, 0.5, 0.5
	SP7	4'/5'		



DESCRIPTION

Clayey SILT; brown to gray; non-plastic; firm to stiff; dry to moist; trace roots/organic matter. (Fill)

ASH; black; non-plastic; moist. (FILL)

Clayey SILT; gray to black; non-plastic; trace organic matter/shells. (OL)

SILT; gray; non-plastic; wet. (ML)

CLAY; gray to black; soft; high plasticity; moist; trace to some organic matter. (OH)

SAND; gray; poorly graded; medium grained; wet. (SP)

Bottom of boring @ 35'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-11-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

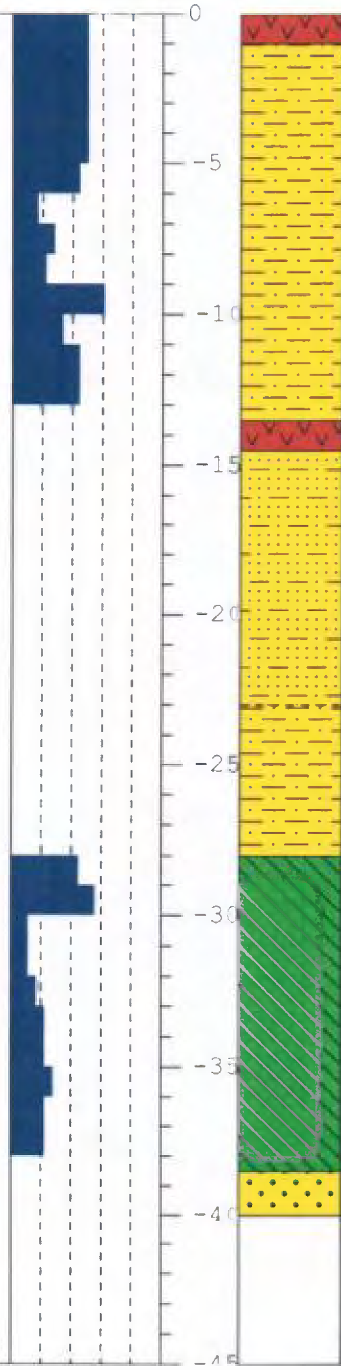
COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*

BORING NO.: *SB3 (CPT10)*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-11-11*
DATE FINISHED: *05-11-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	3.5'/5'		2.25, 2.25, 2.25, 2.25, 2.25
	SP2	5'/5'		2.0, 0.75, 1.25, 1.0, 2.75
▽	SP3	5'/5'		1.5, 2.0, 2.0
	SP4	5'/5'		
	SP5	5'/5'		
	SP6	5'/5'		2.0, 2.5
	SP7	5'/5'		0.5, 0.5, 0.75, 1.0, 1.0
	SP8	5'/5'		1.25, 1.0, 1.0, 1.0

CONSISTENCY vs. DEPTH / DEPTH IN FEET / PROFILE



DESCRIPTION

ASH; brown; non-plastic; moist. (FILL)

Clayey SILT; brown to gray; non-plastic; firm to stiff; dry to moist; trace roots/organic matter. (Fill)

ASH; gray; non-plastic; moist. (FILL)

Silty SAND; dark gray to light gray; poorly graded; fine grained; wet. (SP)

SILT; gray; non-plastic; wet. (ML)

Silty CLAY; gray to black; soft; low plasticity; moist; trace to some organic matter. (OH)

SAND; gray; poorly graded; fine grained; wet. (SP)

Bottom of boring @ 40'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-11-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

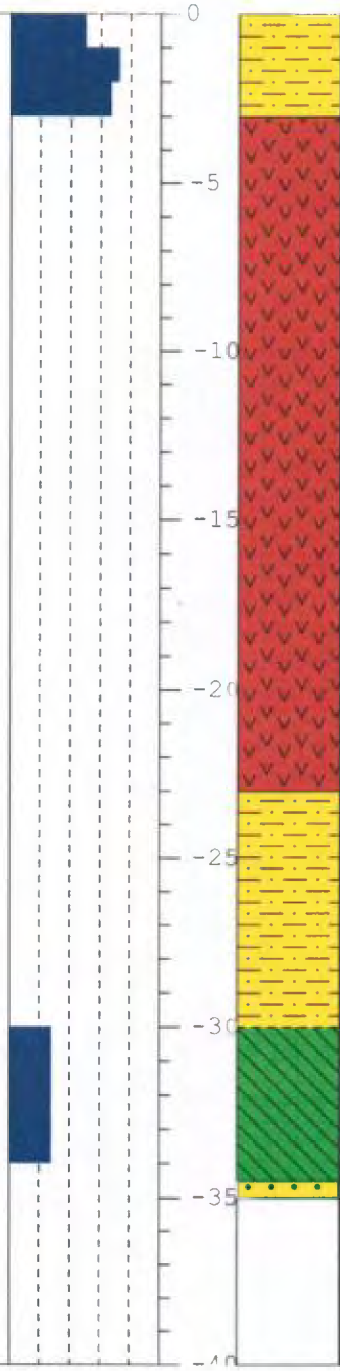
COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: ***SB4 (CPT6)***

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-11-11*
DATE FINISHED: *05-11-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	4.5'/5'		2.25 3.25 3.0
	SP2	5'/5'		
	SP3	5'/5'		
	SP4	5'/5'		
▽	SP5	3.5'/5'		
	SP6	4'/5'		
	SP7	5'/5'		1.25 1.25 1.25 1.25

CONSISTENCY vs. DEPTH — DEPTH IN FEET — PROFILE



DESCRIPTION

Clayey SILT; brown to gray; non-plastic; firm to stiff; dry to moist; trace roots/organic matter. (Fill)

ASH; gray; non-plastic; moist. (FILL)

SILT; gray; non-plastic; wet. (ML)

CLAY; gray to black; low to high plasticity; wet; some organic matter. (OL/OH)

SAND; gray; poorly graded; fine grained; wet. (SP)

Bottom of boring @ 35'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-11-11.

CABENO
Environmental Field Services, LLC

BORING LOG

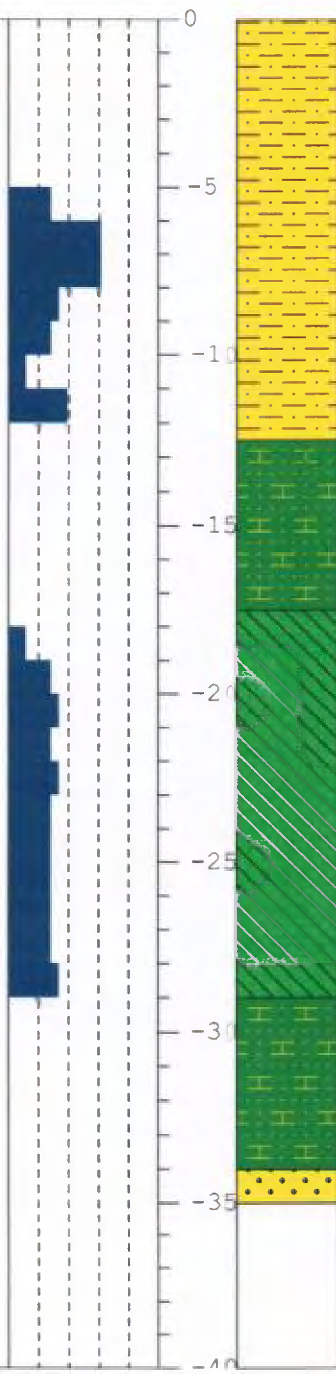
CLIENT: Aether dbs
PROJECT: Burlington, IA

COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*
BORING NO.: ***SB5 (cpt19)***

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	5'/5'		
	SP2	5'/5'		1.25, 2.75, 2.75, 1.5, 1.25, 0.5, 1.75, 2.0
	SP3	4'/5'		
	SP4	4'/5'		0.5, 1.25, 1.5, 1.25, 1.5
	SP5	3.5'/5'		1.25, 1.25, 1.25, 1.25, 1.25, 1.5, 1.25
▽	SP6	3.5'/5'		
	SP7	3'/5'		

CONSISTENCY vs. DEPTH / DEPTH IN FEET / PROFILE



DESCRIPTION

SILT; brown; non-plastic; dry to moist; trace organic matter. (Fill)

@ 5' grades Clayey SILT; low plasticity; firm to stiff.

Sandy CLAY; black to dark gray; non-plastic to low plasticity; moist. (CL)

CLAY; black to dark gray; low to high plasticity; moist; trace organic matter. (CL)

Sandy CLAY; dark gray; low to high plasticity; wet; trace silt. (CL)

@ 33' grades several thin sand seams.

SAND; gray; poorly graded; coarse grained; wet. (SP)

Bottom of boring @ 35'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO
Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

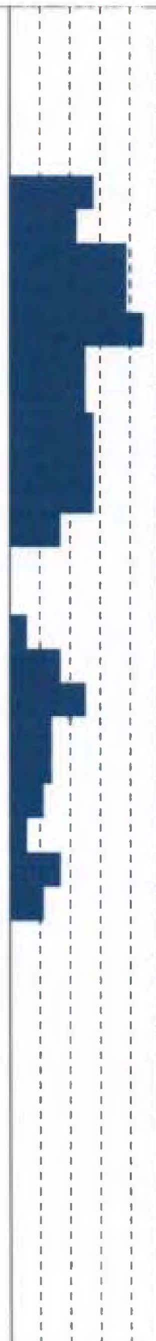
COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SB6 (cpt18)*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

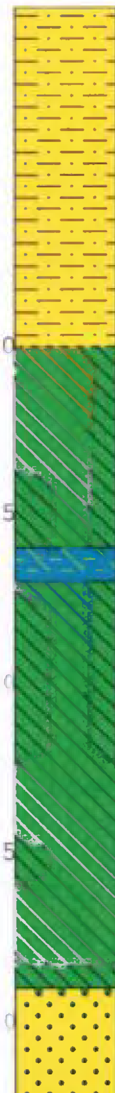
DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	5'/5'		
				2.5
				2.0
	SP2	5'/5'		3.5
				3.5
				4.0
				2.25
				2.25
	SP3	5'/5'		2.5
				2.5
				2.5
▽				2.5
				1.5
	SP4	4.5'/5'		
				0.5
				1.5
				2.25
				1.25
	SP5	2.5'/5'		1.25
				1.0
				0.5
				1.5
				1.0
	SP6	3.8'/5'		0
				0
				0
	SP7	2.5'/2.5'		

CONSISTENCY vs. DEPTH



DEPTH IN FEET: 0, -5, -10, -15, -20, -25, -30, -35, -40

PROFILE



DESCRIPTION

Depth (ft)	Description
0	SILT; brown; non-plastic; dry to moist; trace organic matter (FILL)
5	@ 5' grades Clayey SILT; low plasticity; very stiff.
10	CLAY; gray to olive; low to high plasticity; stiff to very stiff; moist; trace organic matter (Fill)
15	Clayey SAND; gray; poorly graded; medium grained; wet. (SP)
17	CLAY; gray to olive; high plasticity; very soft to firm; moist to wet. (CL) @ 19' is a thin 1" sand seam, wet.
29	SAND; gray; well graded; fine to coarse grained; wet. (SW)
32.5	Bottom of boring @ 32.5' Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

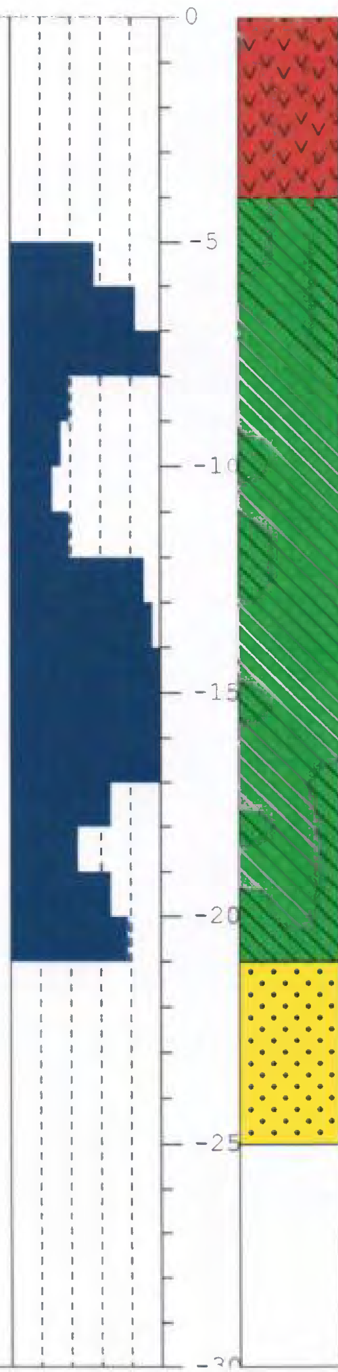
PROJECT: Burlington, IA

COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*

BORING NO.: *SB7 (cpt15)*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	3.8'/5'		
				2.5
				3.75
				>4.5
	SP2	5'/5'		1.75
				1.5
				1.25
				1.75
				4.0
	SP3	5'/5'		4.25
				4.5
				4.5
				>4.5
				3.0
	SP4	5'/5'		2.0
▽				3.0
				3.5
	SP5	3'/5'		



DESCRIPTION

Depth (ft)	Description
0 – 4	ASH; gray; fine grained; moist. (Fill)
4 – 21	CLAY; black; low plasticity; stiff to very stiff; moist; trace organic matter (Fill) @ 18' grades (OH) @ 19' is a 6-inch SAND seam; fine grained; wet. @ 20' grades high plasticity.
21 – 25	SAND; gray; poorly graded; fine grained; wet. (SW)

Bottom of boring @ 25'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*

BORING NO.: ***SB8 (cpt13)***

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	4'/5'		
∇	SP2	4'/5'		2.75 3.5
	SP3	5'/5'		3.0 4.5
	SP4	4'/5'		1.75 1.75 1.0 2.25 2.0
	SP5	4.5'/5'		

CONSISTENCY vs. DEPTH | DEPTH IN FEET (0, -5, -10, -15, -20, -25, -30) | PROFILE

DESCRIPTION

SILT; brown; non-plastic; dry to moist; trace to some gravel, sand & ash. (Fill)

SAND; gray; fine grained; poorly graded; wet. (SP)

CLAY; gray; low to high plasticity; stiff; moist. (CL)

SAND; gray to black; fine grained; poorly graded; wet. (SP)

CLAY; gray; low to high plasticity; stiff; moist. (CL)

SAND; gray; well graded; fine to coarse grained; wet. (SW)

CLAY; dark gray; high plasticity; firm to stiff; moist; trace organic matter. (OH)

SAND; gray to black; poorly graded; fine grained; wet. (SP)

Bottom of boring @ 25'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

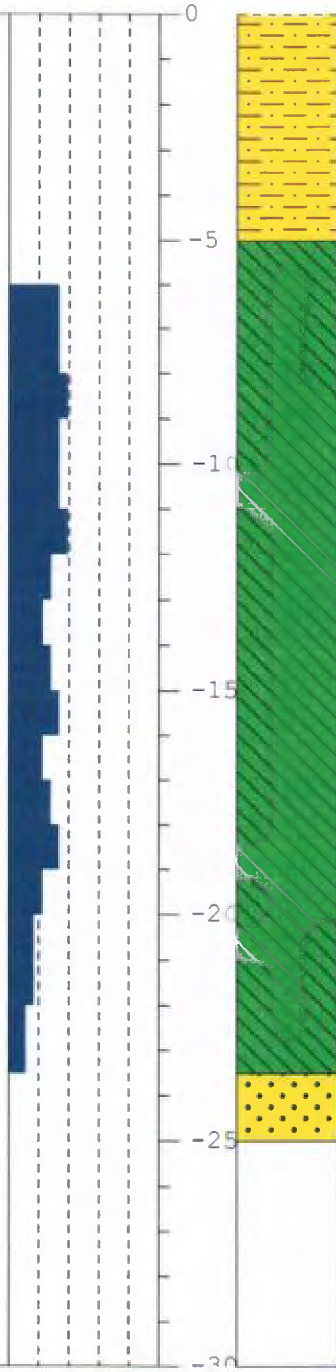
COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SB9 (cpt21)*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	2.5'/5'		
	SP2	4'/5'		
	SP3	4.5'/5'		
	SP4	5'/5'		
▽	SP5	3.5'/5'		

Pocket penetrometer (tons/ft2), top to bottom: 1.5, 1.5, 1.75, 1.5, 1.5, 1.75, 1.25, 1.0, 1.25, 1.5, 1.0, 1.25, 1.5, 1.0, 0.75, 0.75, 0.5, 0.5



DESCRIPTION

SILT; brown; non-plastic; dry to moist; trace organic matter. (Fill)

CLAY:gray to olive; low to high plasticity; moist; trace organics. (OH)

SAND; gray; fine grained; poorly graded; wet. (SP)

Bottom of boring @ 25'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

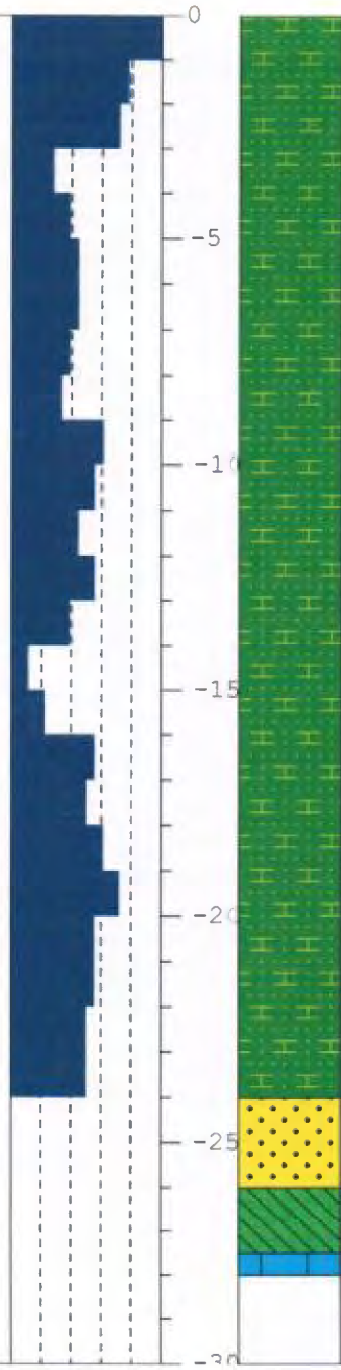
COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SB10*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
				>4.5
				3.5
	SP1	2.5'/5'		
				3.25
				1.25
				1.75
				2.0
				2.0
	SP2	4'/5'		
				1.75
				1.5
				2.75
				2.5
				2.0
	SP3	4.5'/5'		
				2.5
				1.75
				0.5
				1.0
				2.5
	SP4	5'/5'		
				2.25
				2.75
				3.25
				2.5
				2.5
	SP5	3.5'/5'		
				2.25
▽				
	SP6	2'/3'		

CONSISTENCY vs. DEPTH / DEPTH IN FEET / PROFILE



DESCRIPTION

Silty CLAY; brown; low plasticity; firm to very stiff; moist; trace organics and gravels. (CL - OH)

SAND; gray to brown; well graded; fine to coarse grained; wet. (SW)

CLAY; gray; high plasticity; moist. (CL)

LIMESTONE; gray; thinly bedded; highly weathered. (Bedrock)

Bottom of boring @ 25'
Boring advanced W/ Geoprobe Model 6610DT using

CABENO
Environmental Field Services, LLC

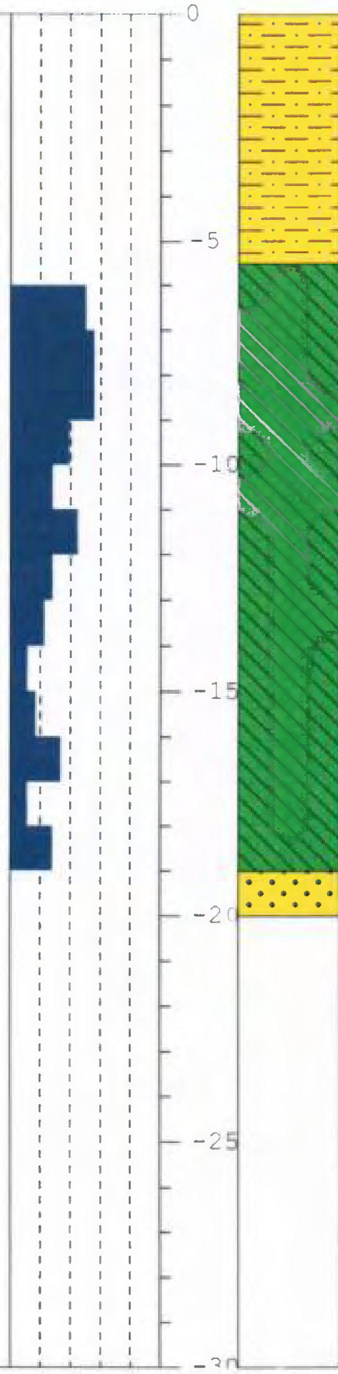
BORING LOG

CLIENT: Aether dbs
PROJECT: Burlington, IA
COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*
BORING NO.: *SB11*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	2.5'/5'		
	SP2	4'/5'		2.25, 2.5, 2.5, 1.75, 1.25
	SP3	4.5'/5'		2.0, 1.25, 1.0, 0.5, 0.75
∇				
	SP4	5'/5'		1.5, 0.5, 1.25, 1.0

CONSISTENCY vs. DEPTH / DEPTH IN FEET / PROFILE



DESCRIPTION

Gravely SILT; brown; non-plastic; dry to moist. (Fill)

CLAY; brown; high plasticity; moist; stiff to soft; trace sand & gravel. (CL)

@ 11.5' grades black to gray, trace organics. (OH)

@ 14.5' are several thin, 1-inch, fine grained sand seams; wet.

SAND; gray; poorly graded; fine grained; wet. (SP)

Bottom of boring @ 20'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

PROJECT: Burlington, IA

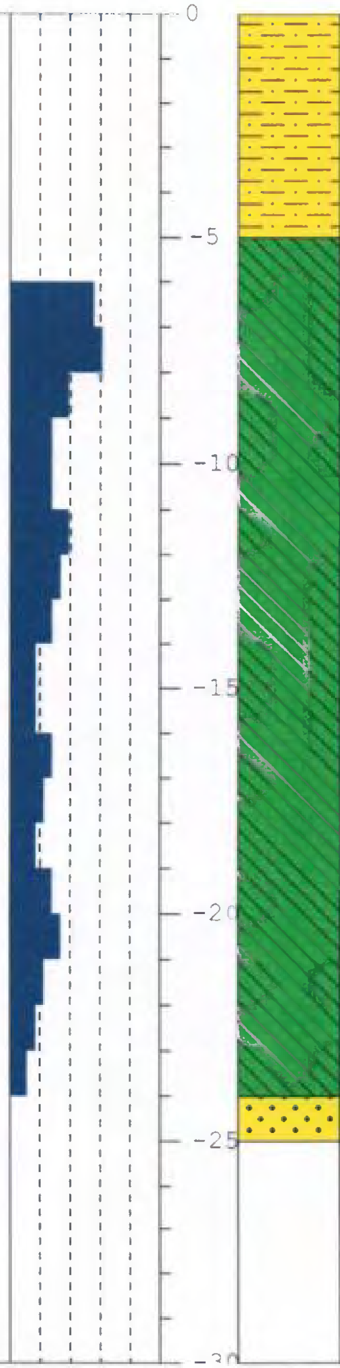
COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*

BORING NO.: *SB12*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *05-16-11*
DATE FINISHED: *05-16-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)
	SP1	2.5'/5'		
				2.5
				2.75
	SP2	5'/5'		1.75
				1.25
				1.25
				1.75
				1.5
	SP3	5'/5'		1.25
				0.75
				0.75
				1.25
				1.0
	SP4	4.5'/5'		0.75
				1.25
				1.5
				1.0
	SP5	5'/5'		0.75
▽				0.5

CONSISTENCY vs. DEPTH / DEPTH IN FEET / PROFILE



DESCRIPTION

Gravely SILT; brown; non-plastic; dry to moist. (Fill)

CLAY; brown; high plasticity; moist; stiff to soft; trace sand & gravel. (CL)

@ 14' grades dark gray to black; trace organics. (OH)

SAND; black to dark gray; poorly graded; fine grained; wet. (SP)

Bottom of boring @ 25'

Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 05-16-11.

APPENDIX C – CPT Soil Probes on CCR Embankments

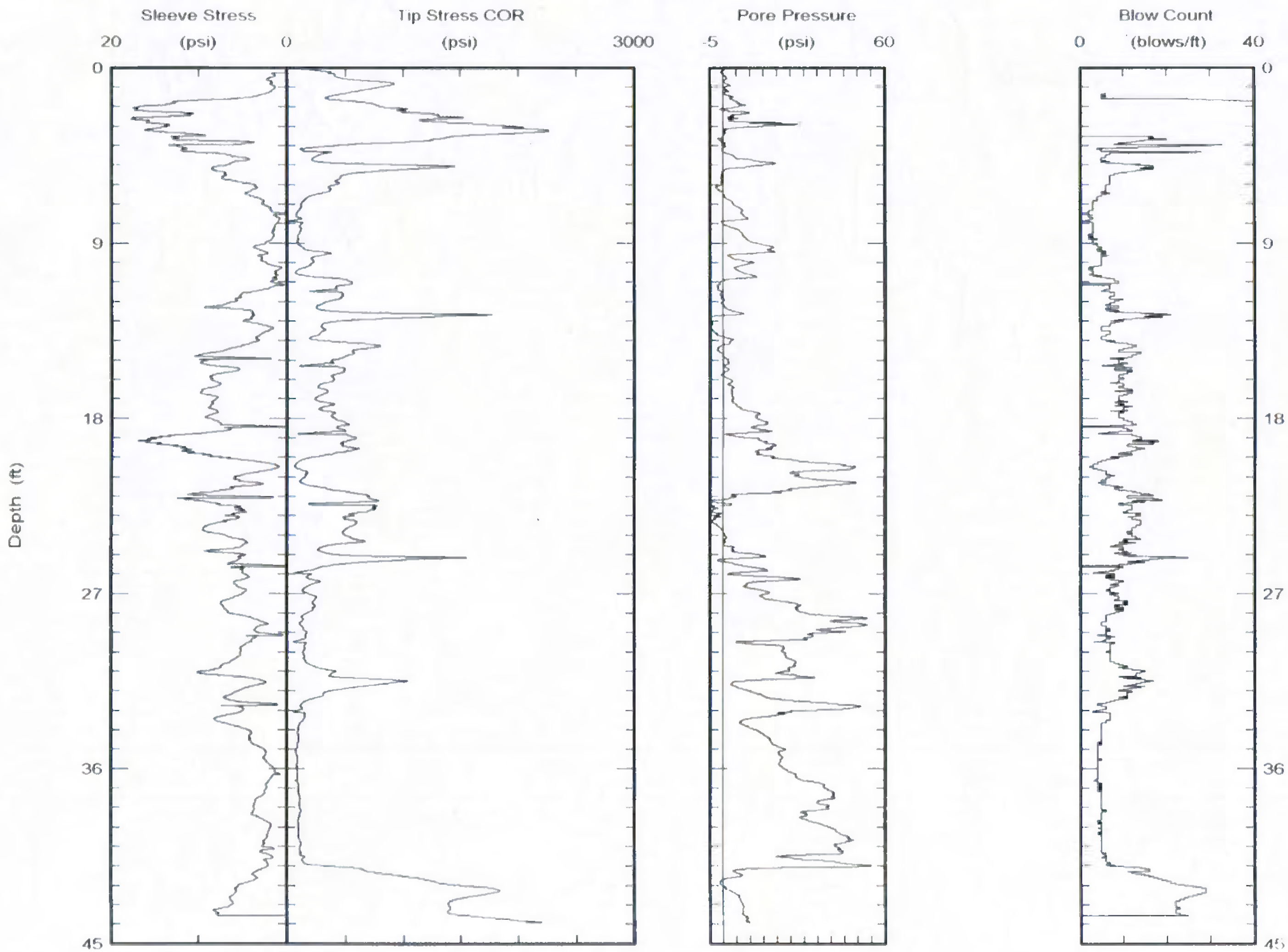
Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

Safety Factor Assessment

CONE PENETROMETER TEST (CPT)

CPT I.D.	LOCATION	GROUND ELEVATION (FT)
CPT-1	Economizer Ash Pond	548.78
CPT-2	Economizer Ash Pond	550.34
CPT-3	Economizer Ash Pond	549.91
CPT-4	Economizer Ash Pond	549.65
CPT-5	Economizer Ash Pond	549.74
CPT-6	Economizer Ash Pond	550.57
CPT-7	Economizer Ash Pond	545.78
CPT-8	Economizer Ash Pond	546.26
CPT-9	Economizer Ash Pond	549.48
CPT-10	Economizer Ash Pond	549.42
CPT-11	Economizer Ash Pond	547.86
CPT-12	Economizer Ash Pond	548.25
CPT-13	Ash Seal Water Pond	534.22
CPT-14	Ash Seal Water Pond	533.67
CPT-15	Main Ash Pond	536.75
CPT-16	Main Ash Pond	534.84
CPT-17	Main Ash Pond	534.52
CPT-18	Main Ash Pond	533.89
CPT-19	Main Ash Pond	535.32
CPT-20	Upper Ash Pond	530.47
CPT-21	Upper Ash Pond	530.42

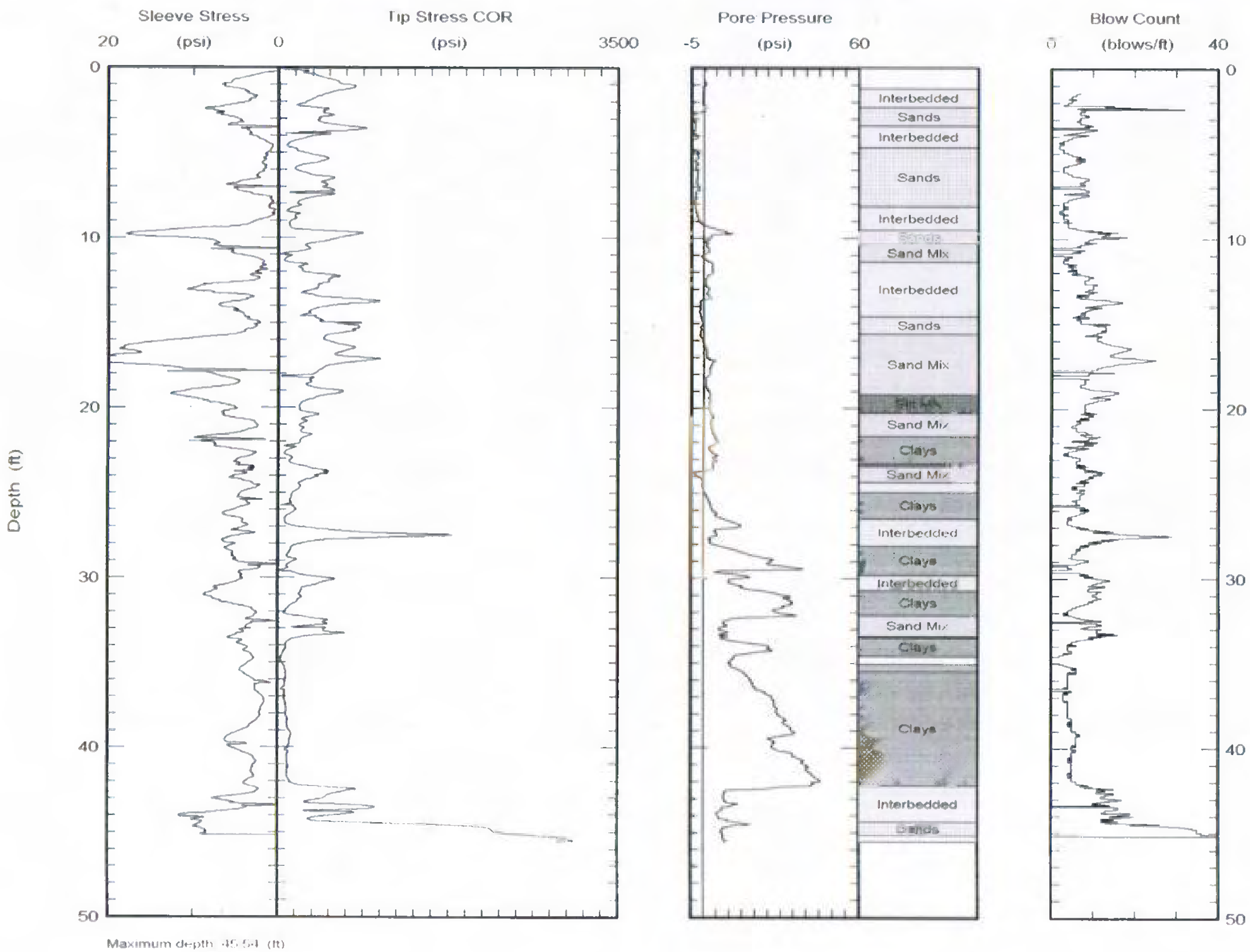
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 09/May/2011 Test ID: cpt1 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



Maximum depth: 43.92 (ft)

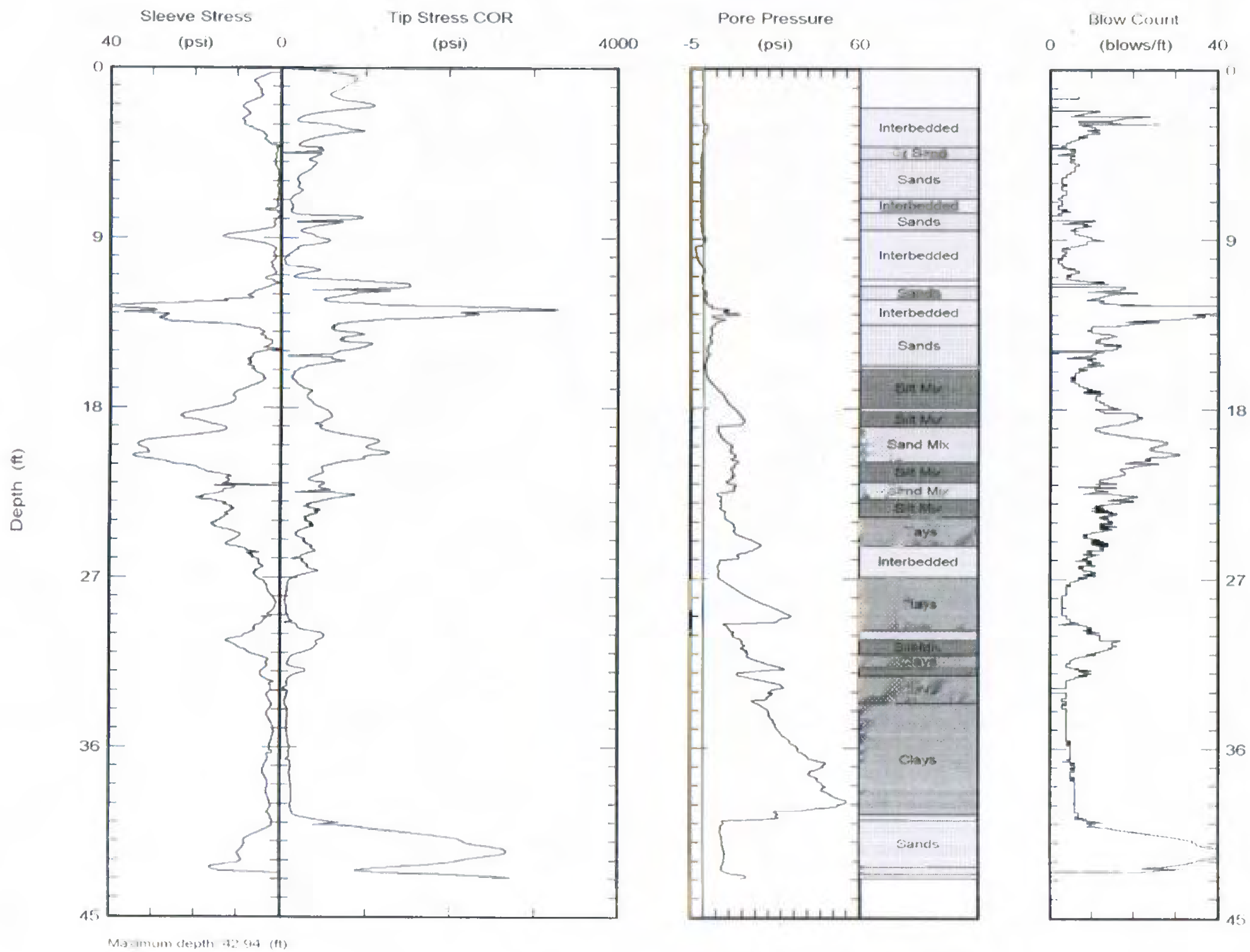
11/25/2020 - Classification: Internal - ECRM7803923

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 09/May/2011 Test ID: cpt2 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



11/25/2020 - Classification: Internal - ECRM7803923

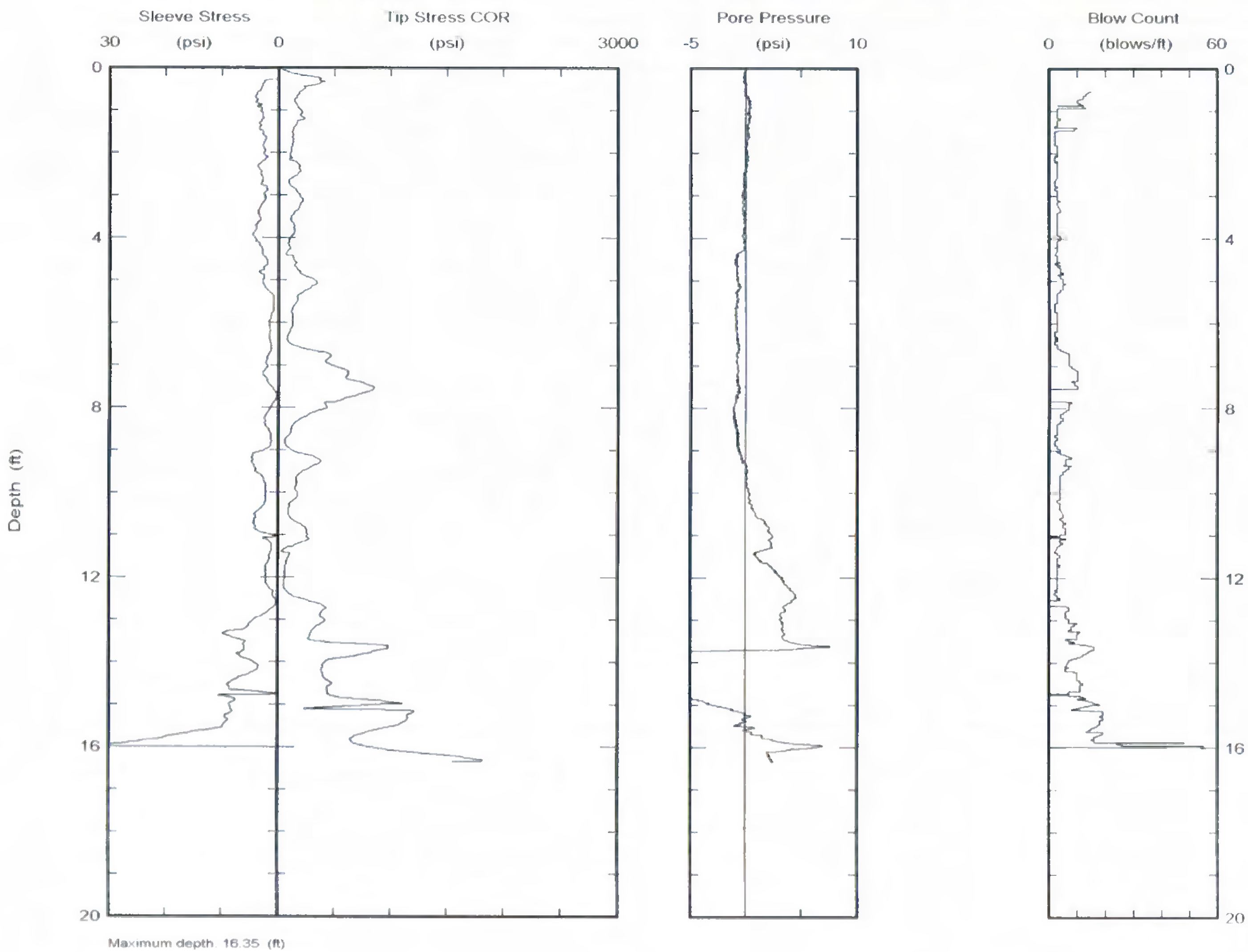
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 09/May/2011 Test ID: cpt3 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



11/25/2020 - Classification: Internal - ECRM7803923

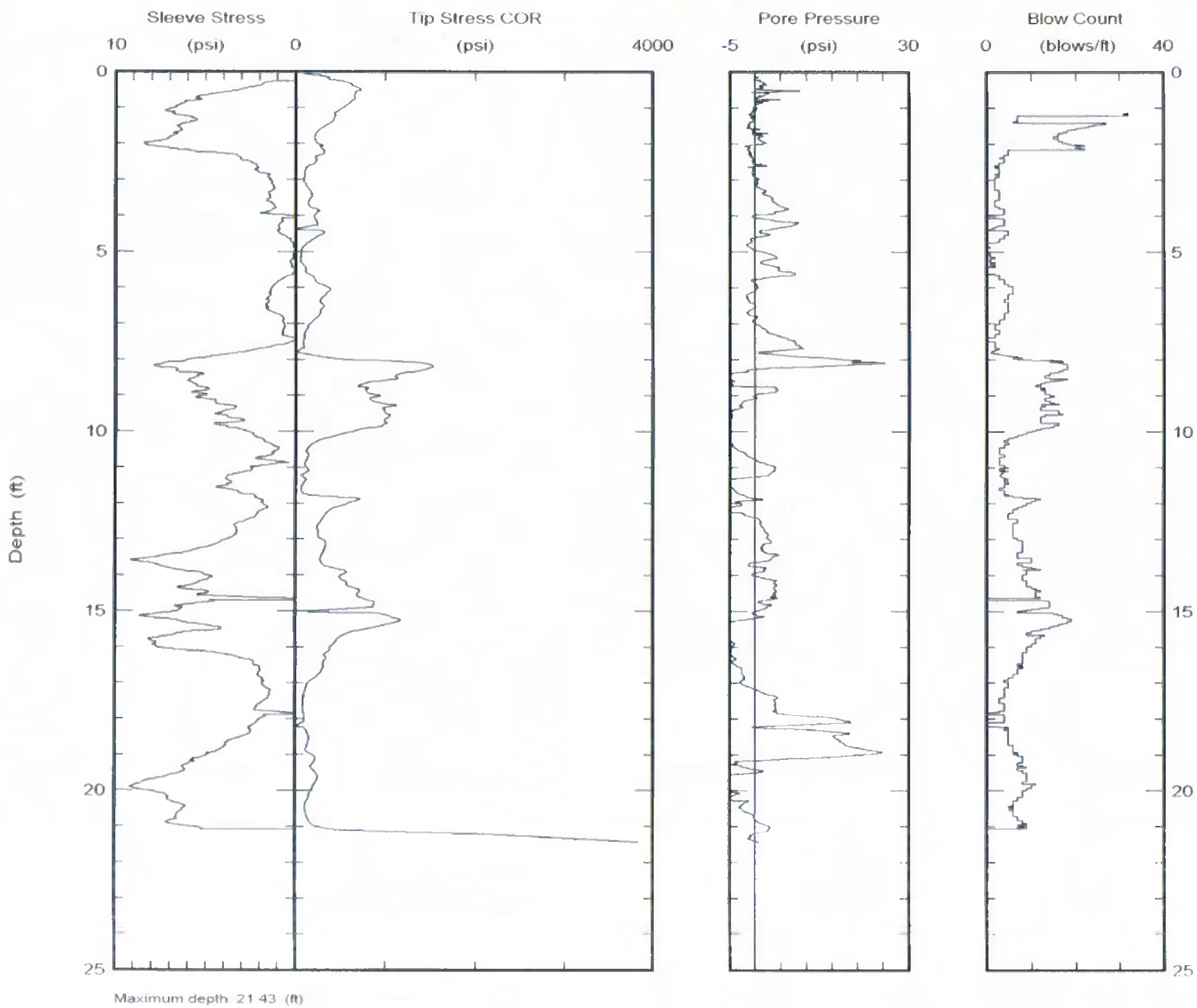
Test ID: cpt3
File: A09Y1103C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 09/May/2011 Test ID: cpt4 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



11/25/2020 - Classification: Internal - ECRM7803923

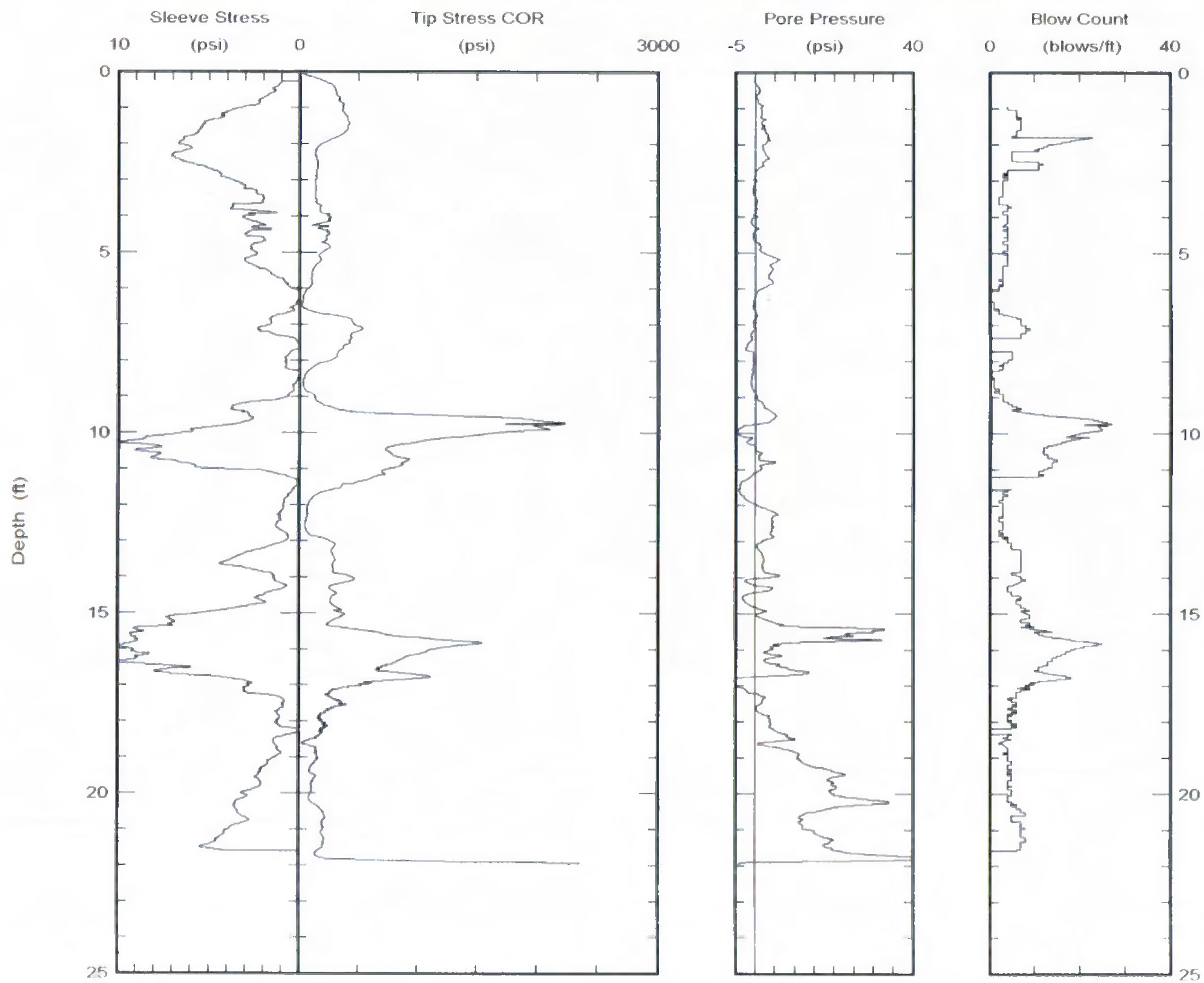
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt5 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt5
File: A10Y1101C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt6 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

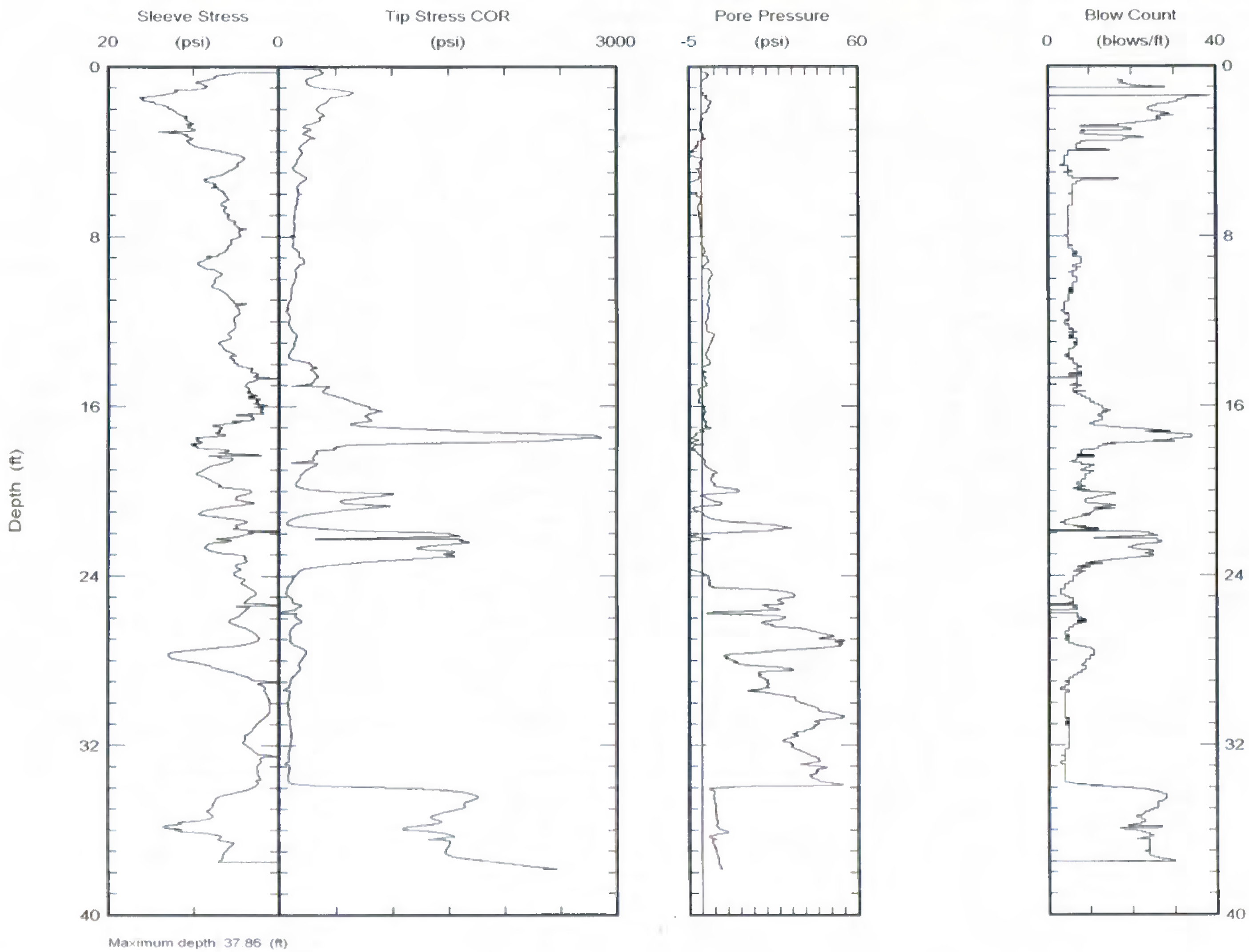


Maximum depth: 21.96 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt6
File: A10Y1102C.ECP

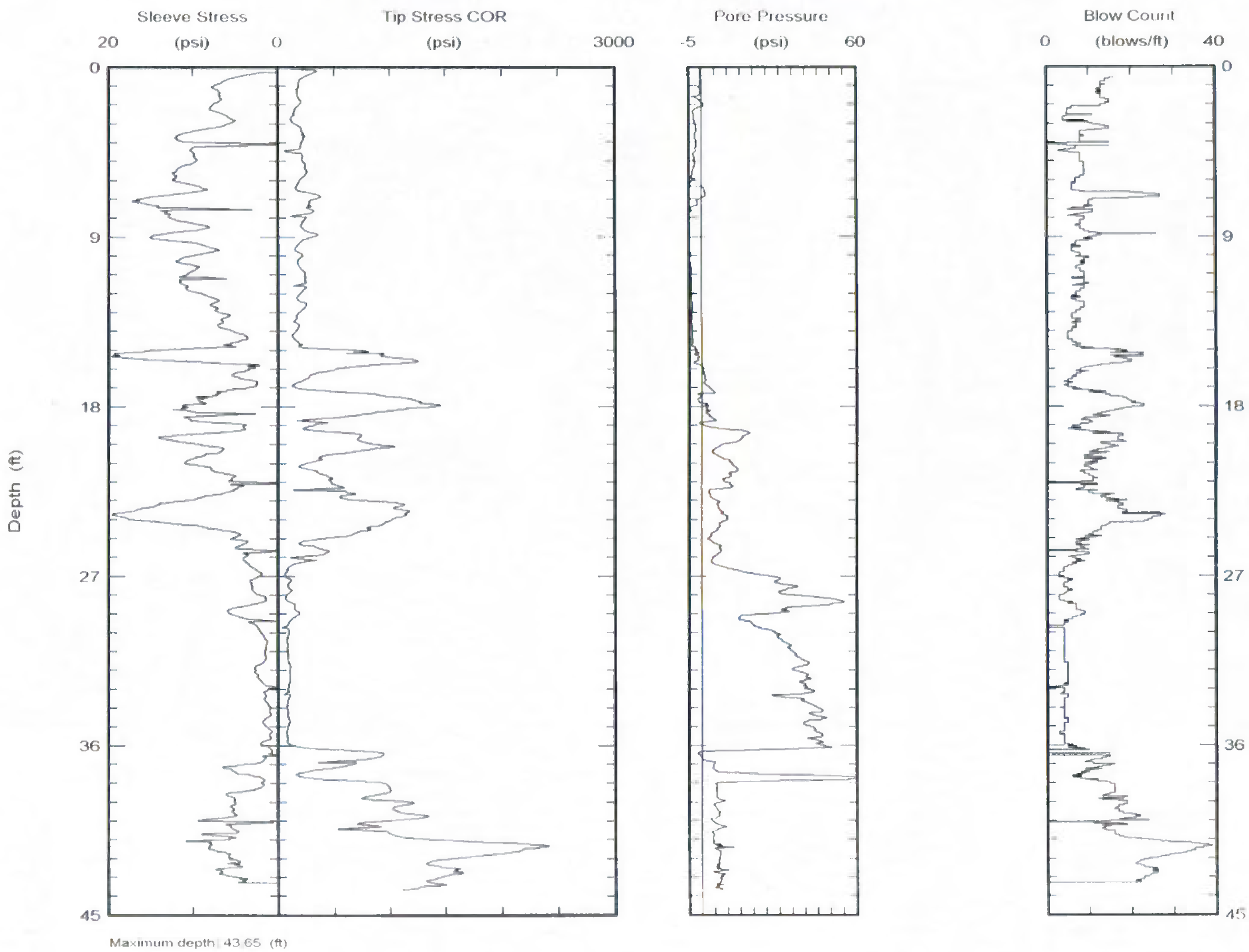
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt7 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



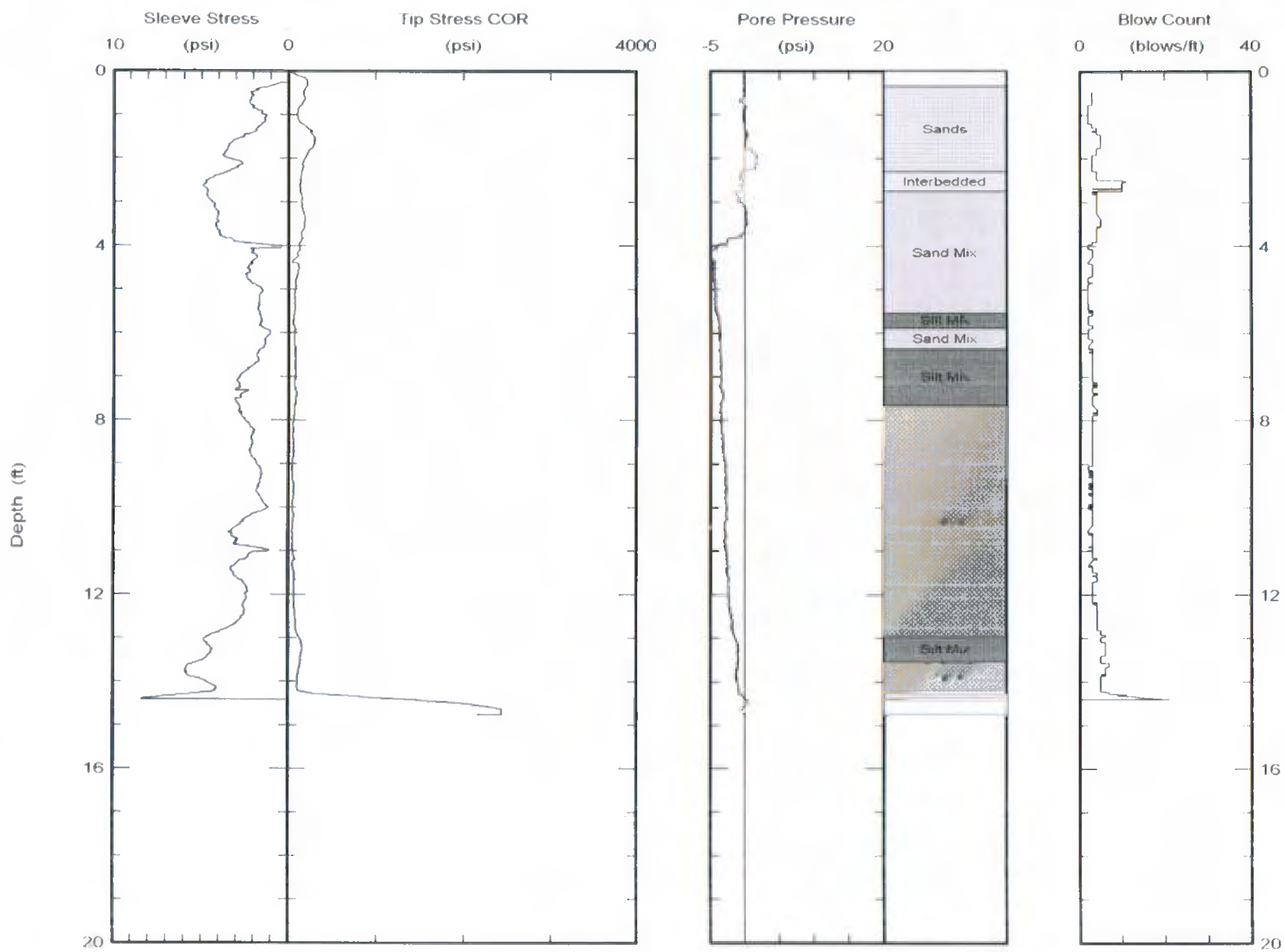
11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt7
File: A10Y1103C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt8 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt9 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



Maximum depth 14.76 (ft)

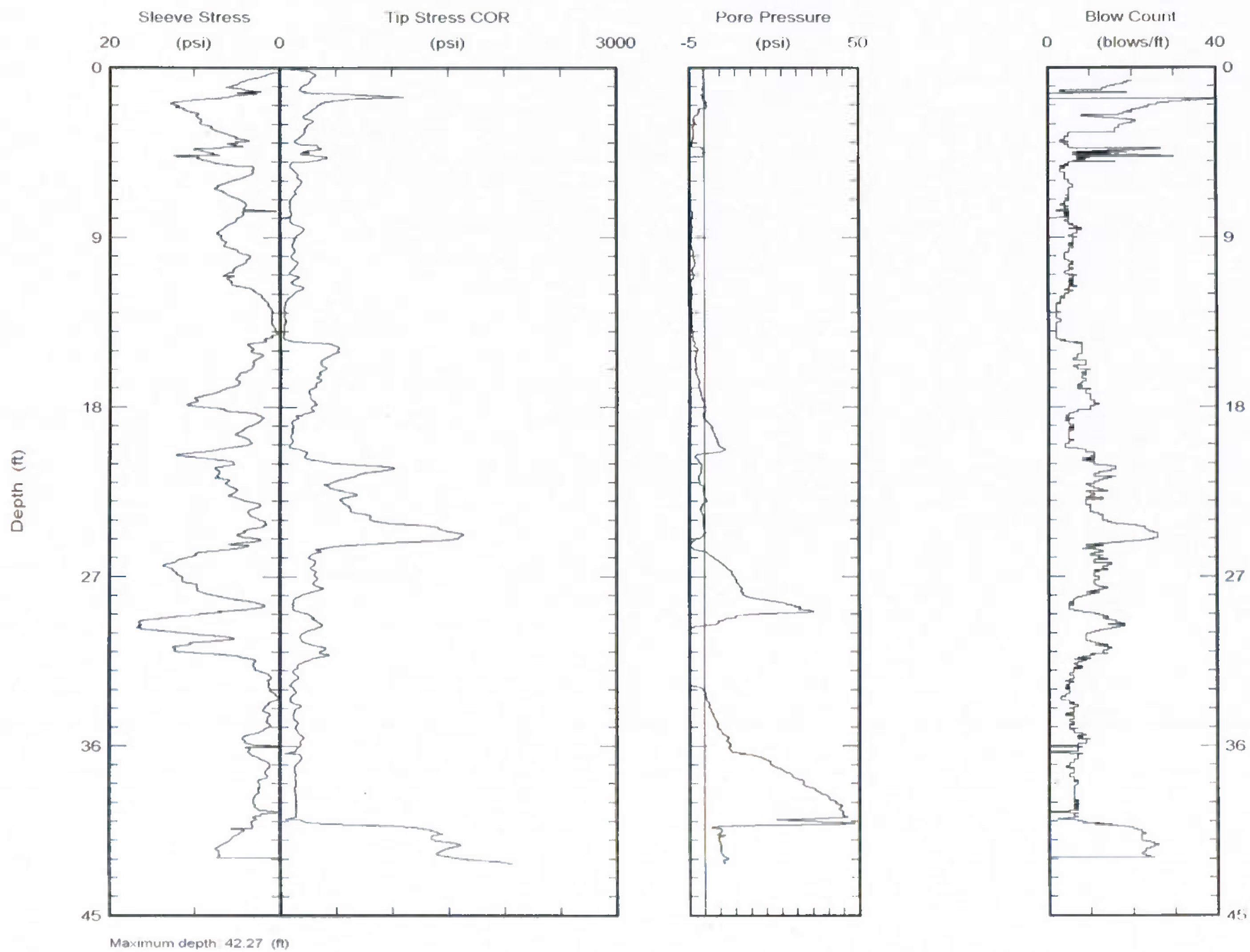
11/25/2020 - Classification: Internal - ECRM7803923

Test ID cpt9
File A10Y1105C ECP

Applied Research Associates, Inc.
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com

Northing:
Easting:
Elevation:
Client: Aetherdbs
Job Site: Burlington

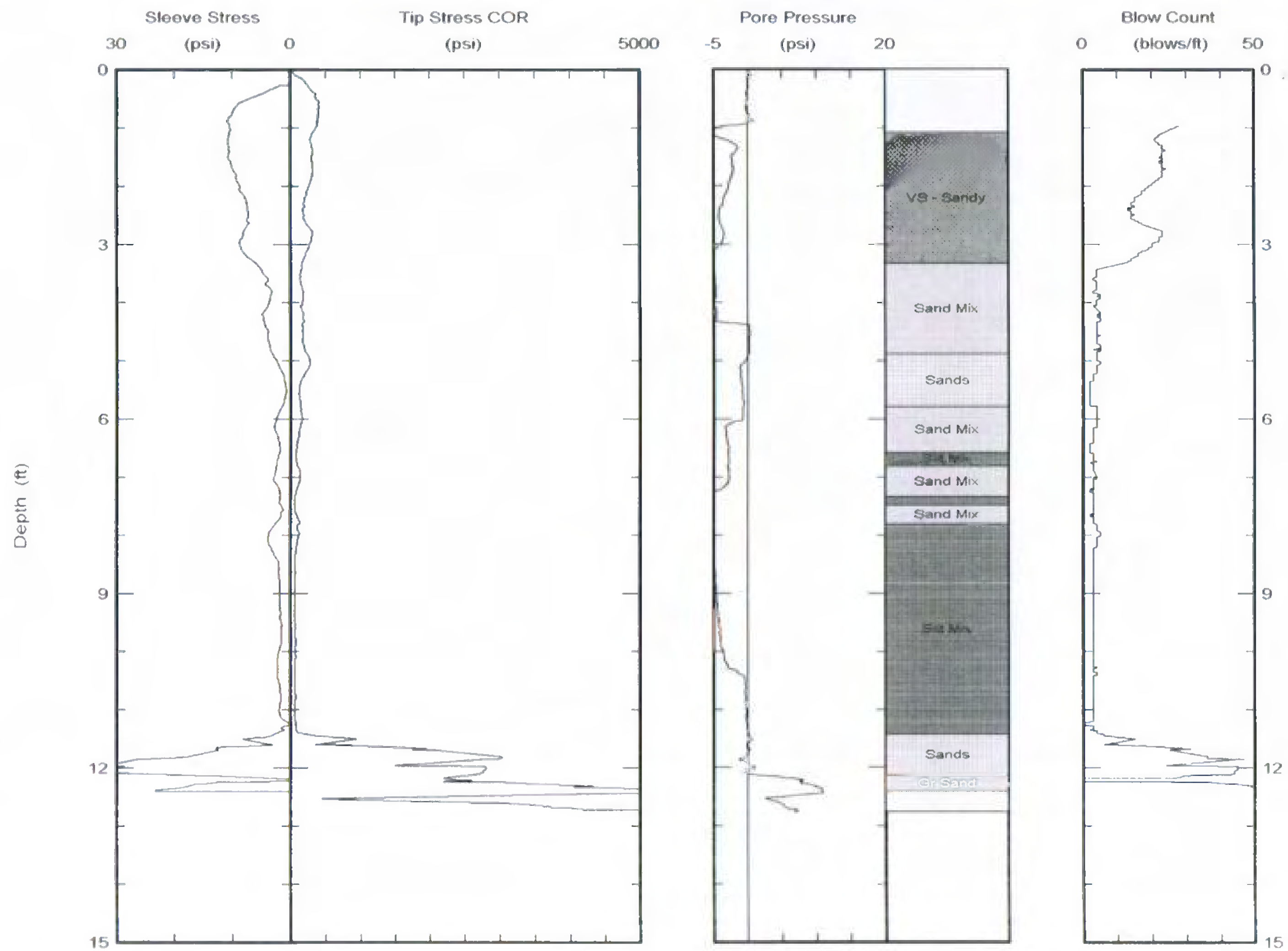
Date: 10/May/2011
Test ID: cpt10
Project: Alliant



11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt10
File: A10Y1106C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt11 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

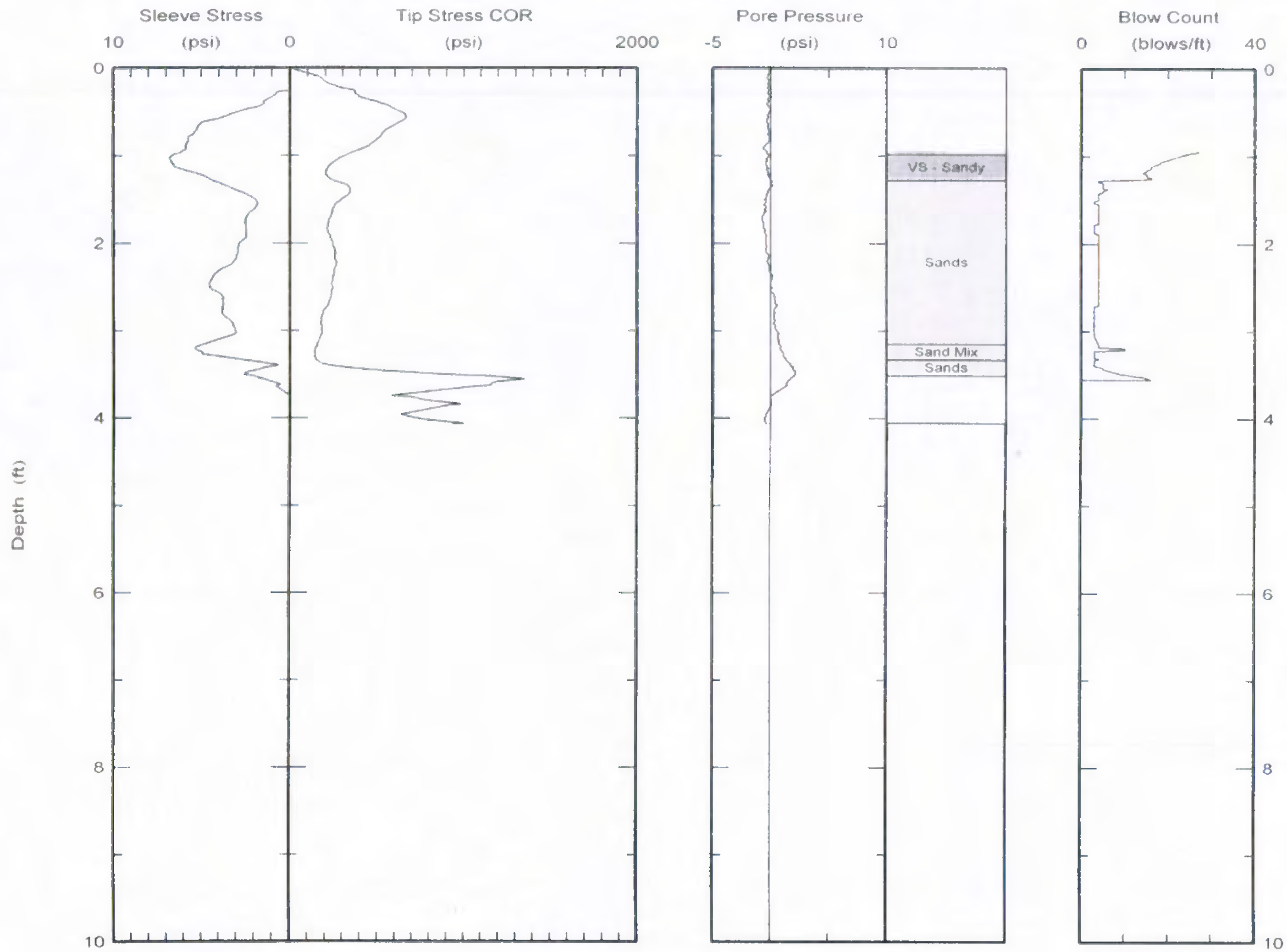


Maximum depth: 12.76 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

Test ID cpt11
File A10Y1107C ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt12 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

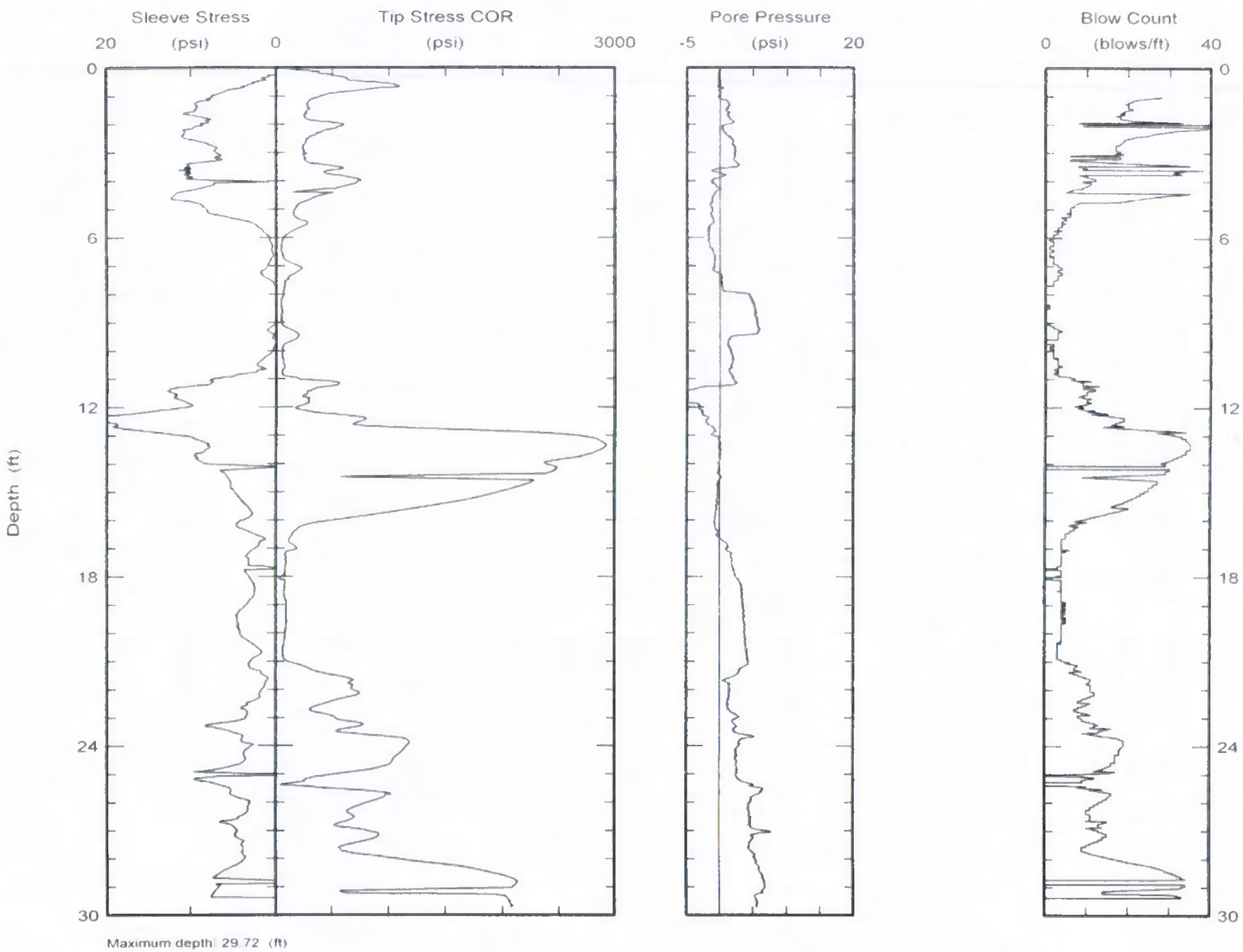


Maximum depth: 4.06 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt12
File: A10Y1108C.ECP

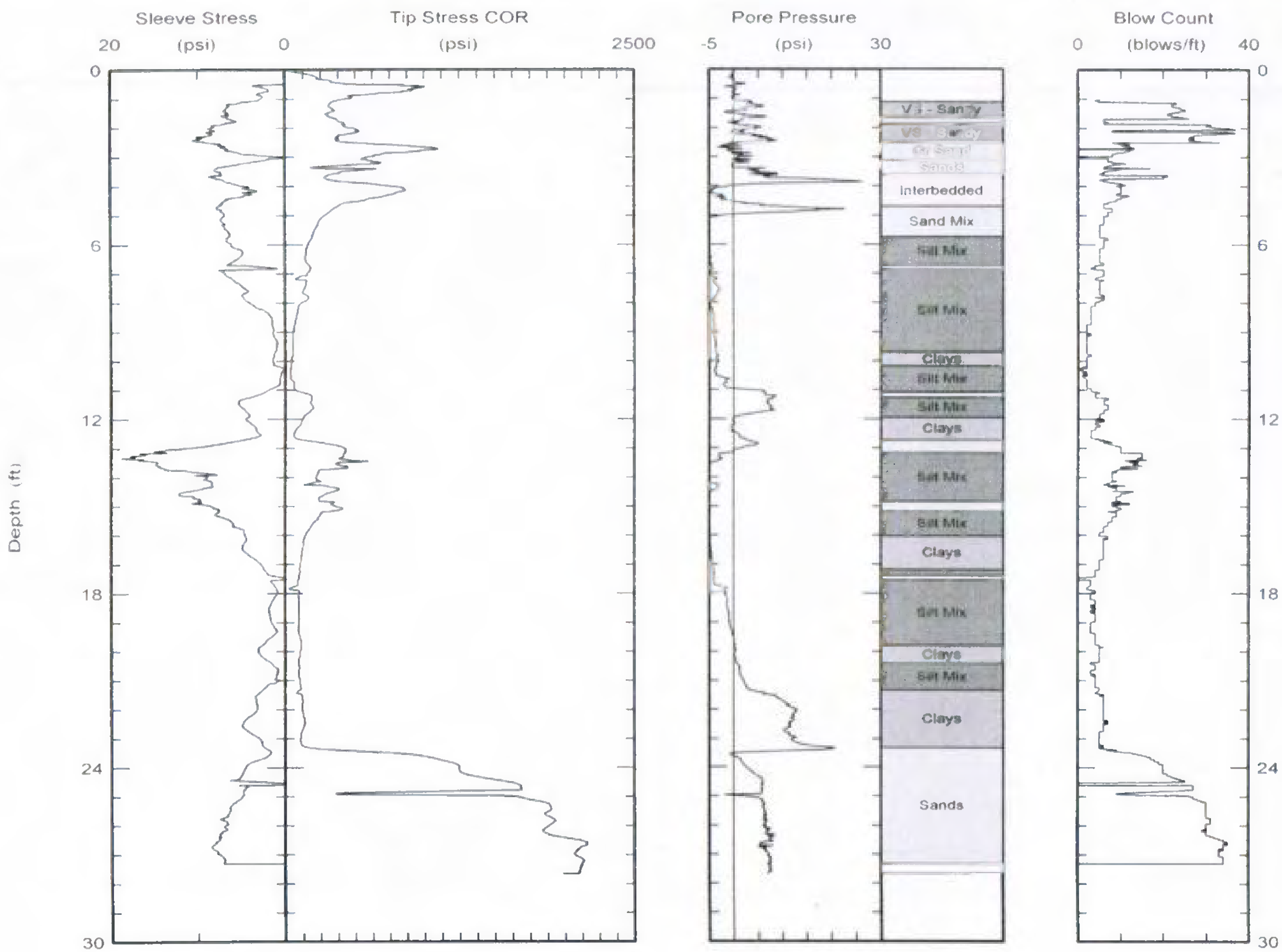
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 10/May/2011 Test ID: cpt13 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt13
File: A10Y1109C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 15/May/2011 Test ID: cpt14 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

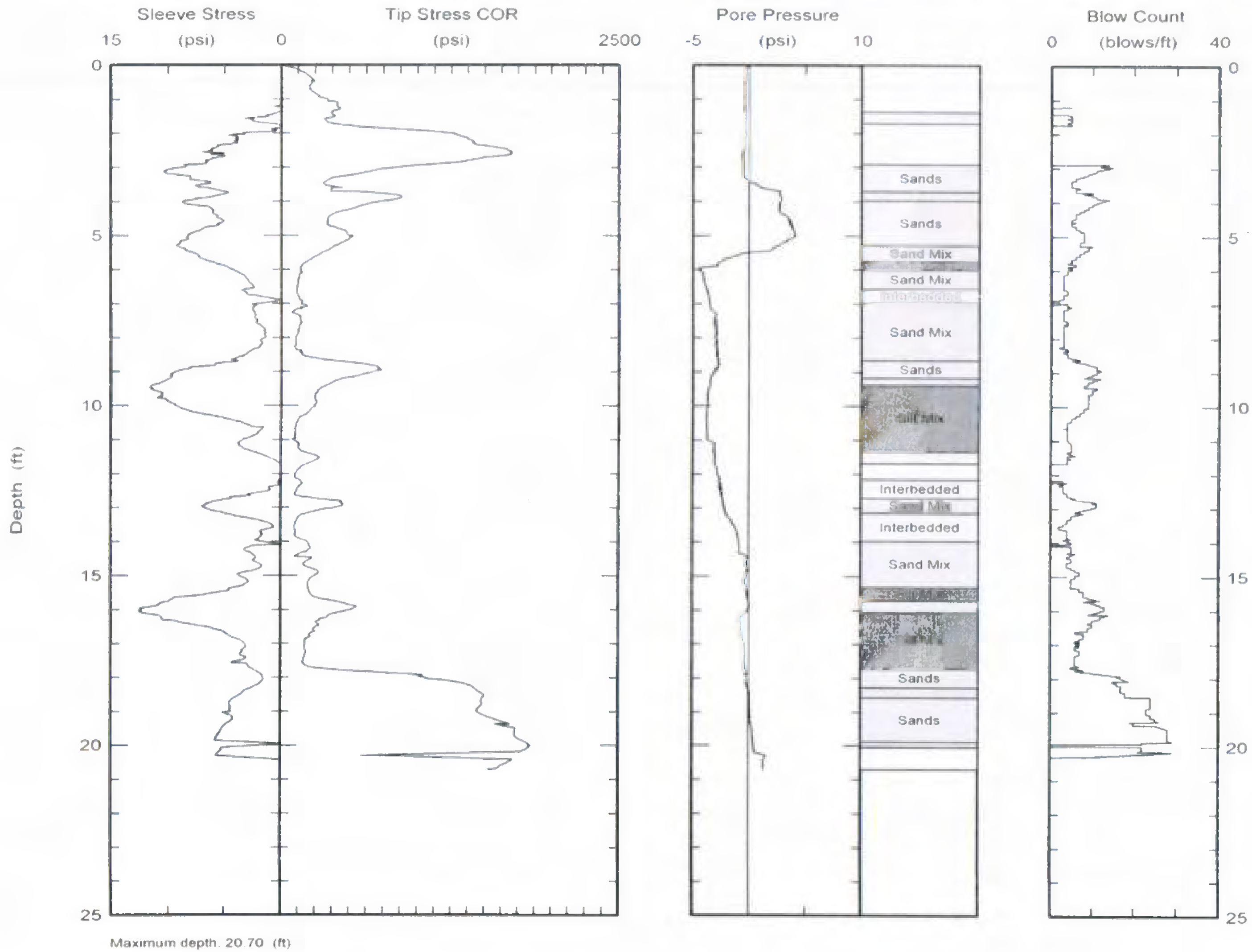


Maximum depth: 27.65 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt14
File: A15Y1101C.ECP

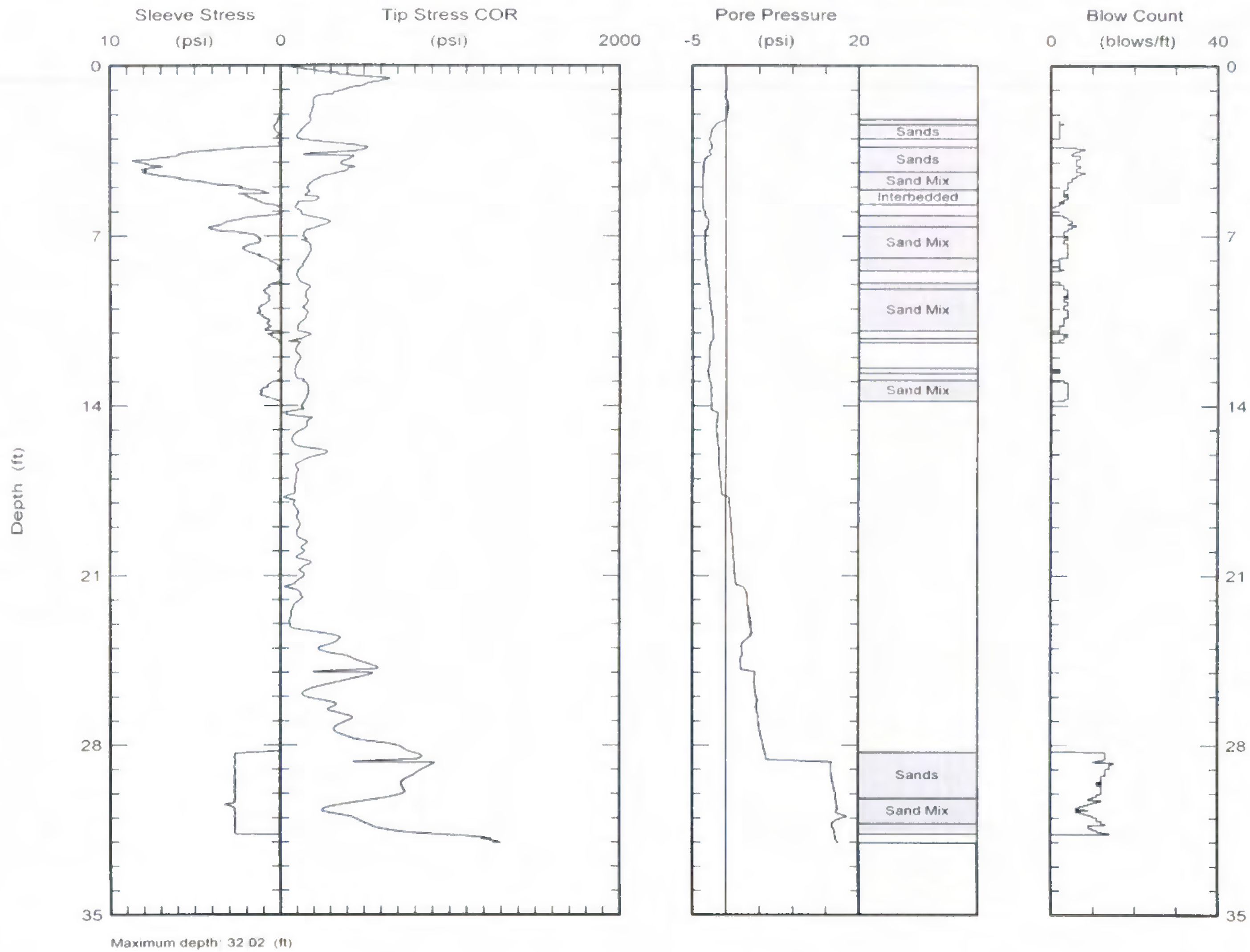
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 15/May/2011 Test ID: cpt15 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt15
File: A15Y1102C.ECP

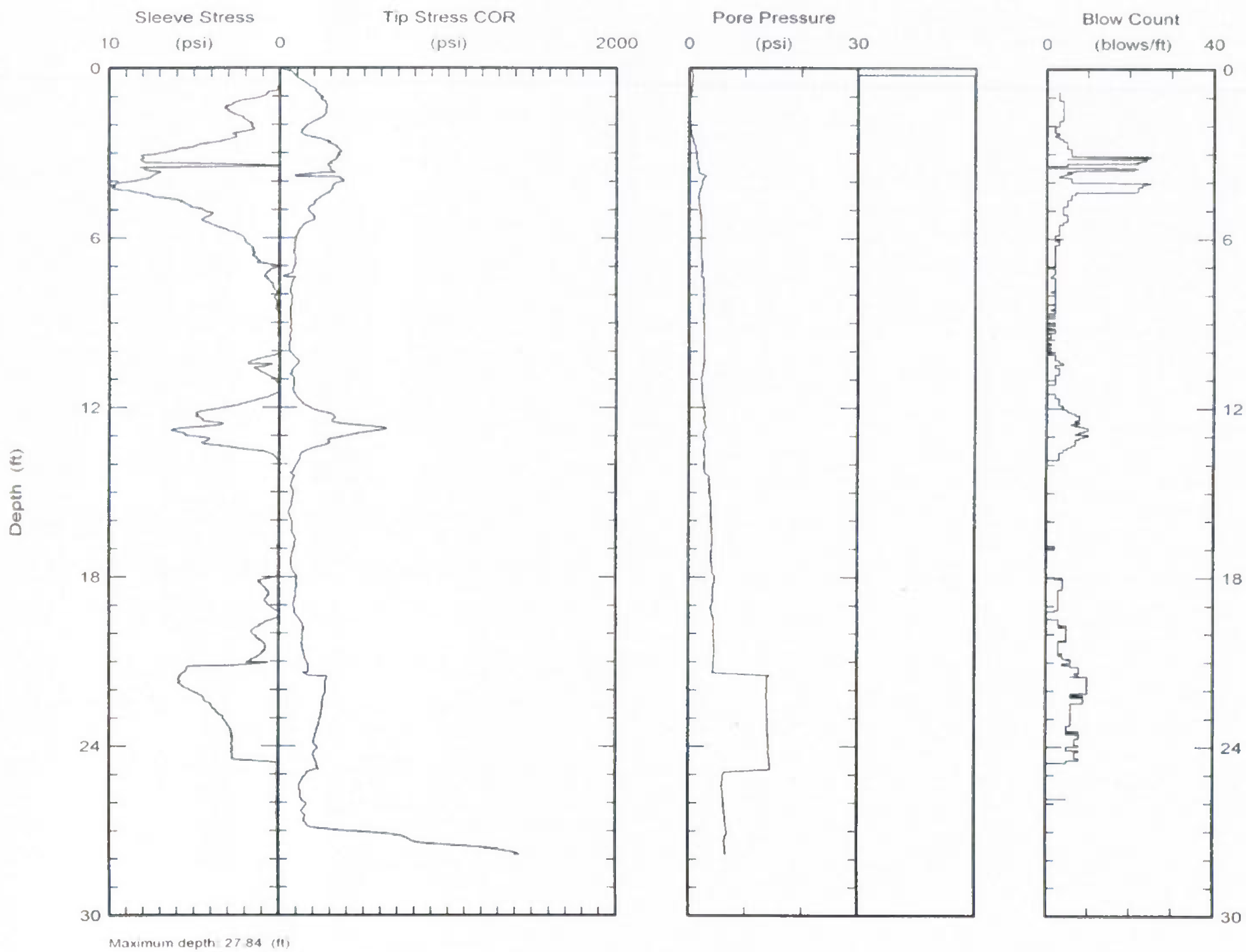
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 15/May/2011 Test ID: cpt16 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt16
File: A15Y1103C.ECP

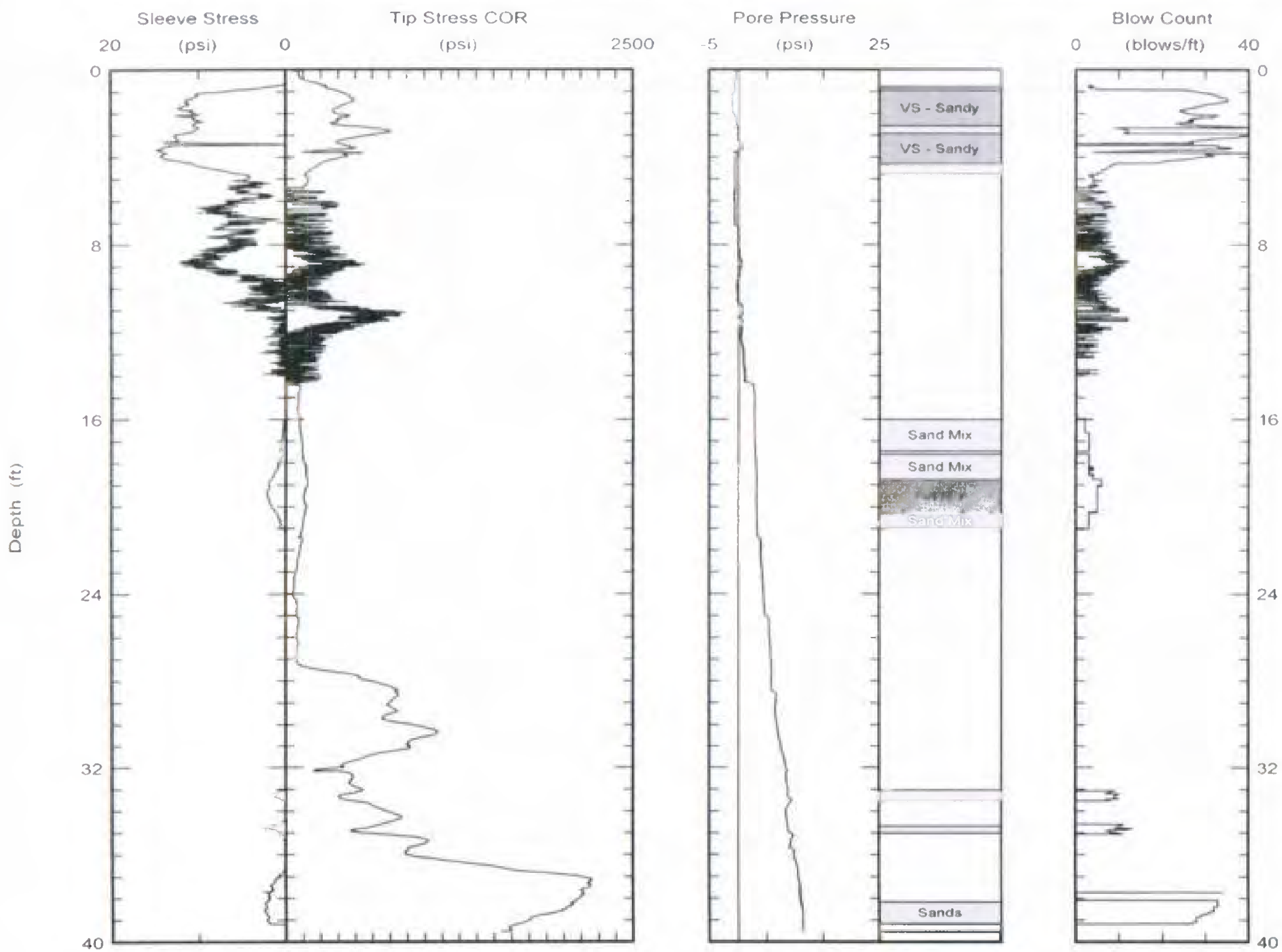
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 15/May/2011 Test ID: cpt17 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt17
File: A15Y1104C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 15/May/2011 Test ID: cpt18 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

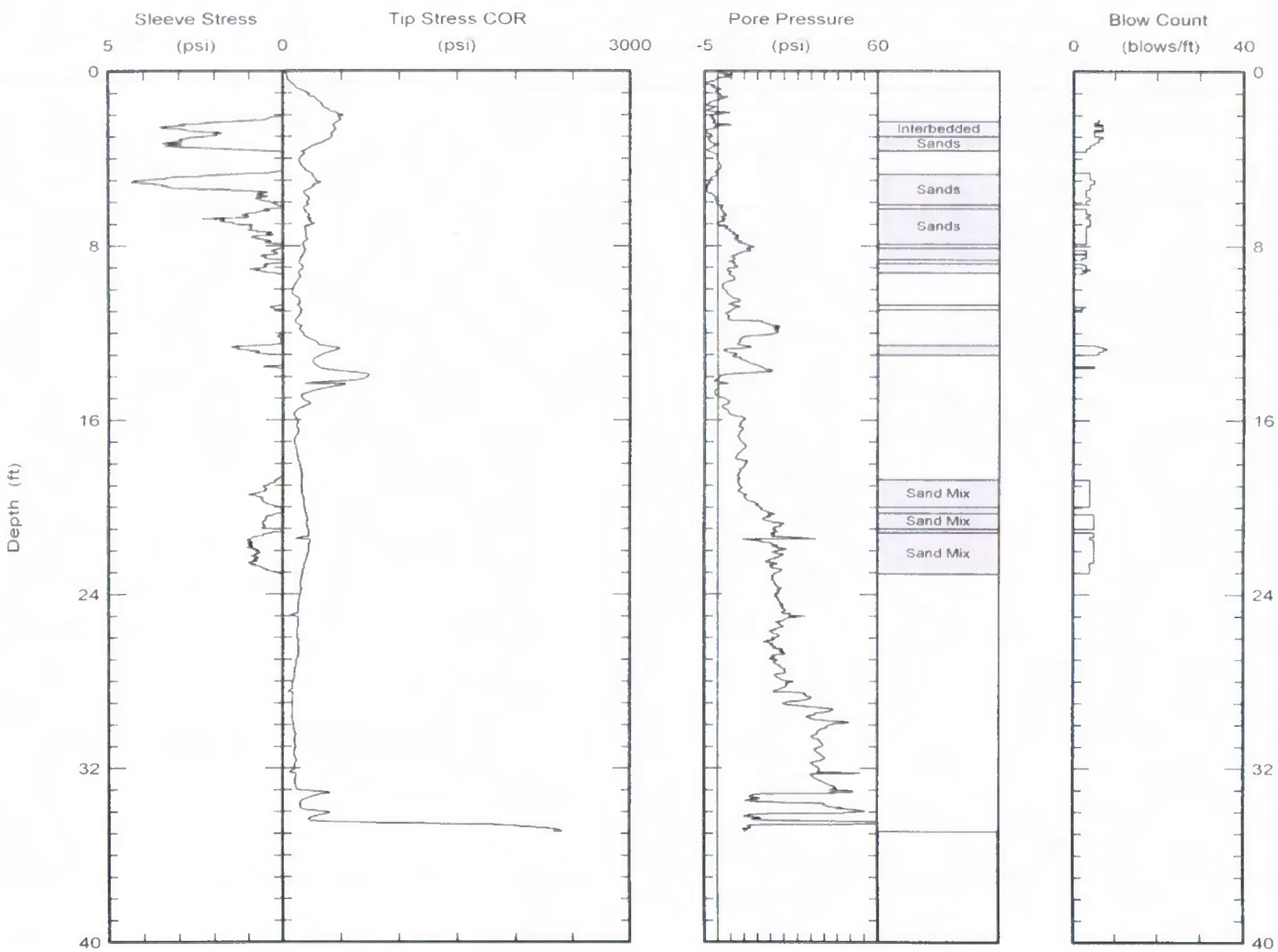


Maximum depth: 39.53 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt18
File: A15Y1105C.ECP

	Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 16/May/2011 Test ID: cpt19 Project: Alliant
		Client: Aetherdbs Job Site: Burlington	

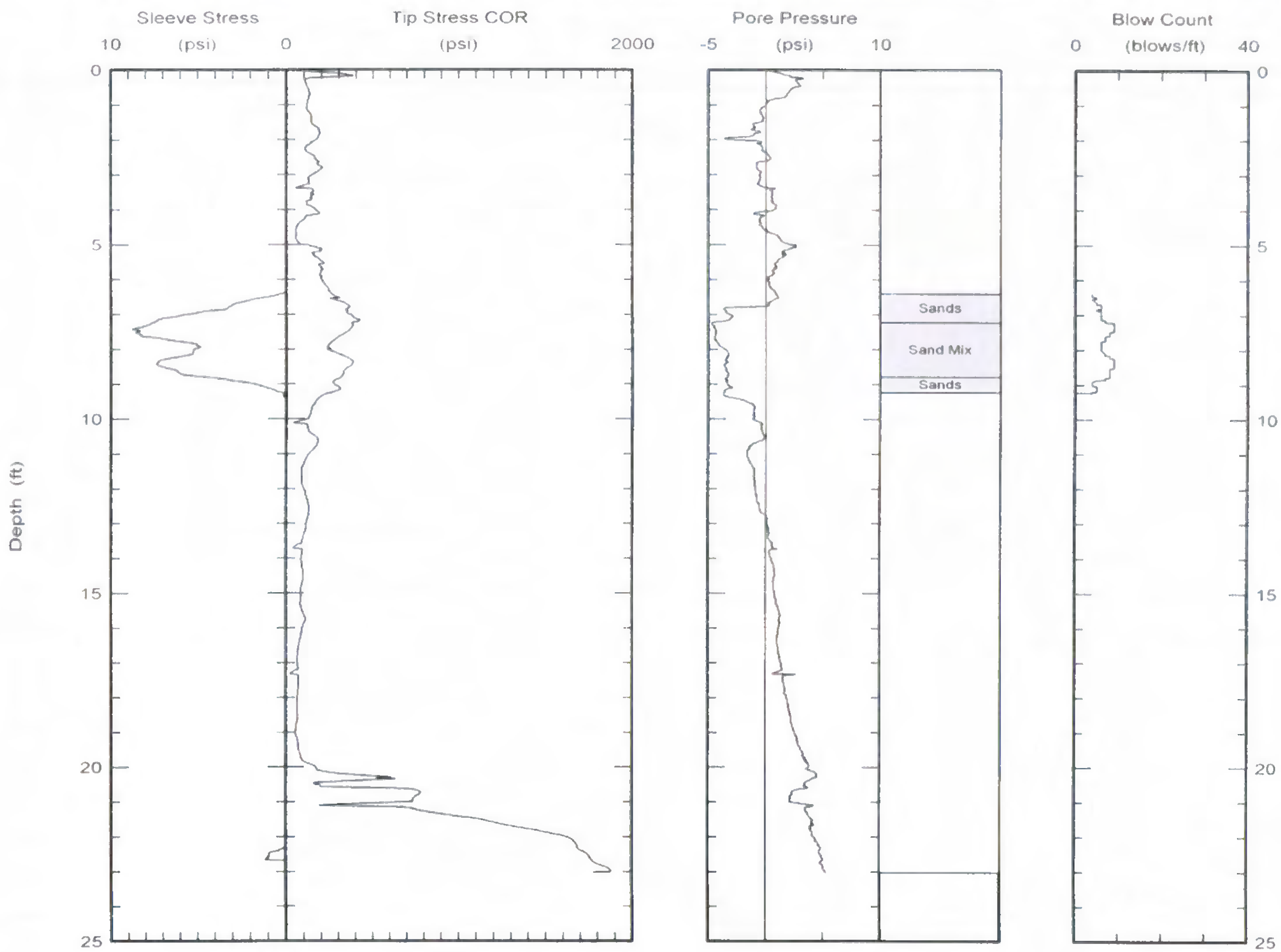


Maximum depth: 34.90 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt19
File: A16Y1101C.ECP

Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 16/May/2011 Test ID: cpt20 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	

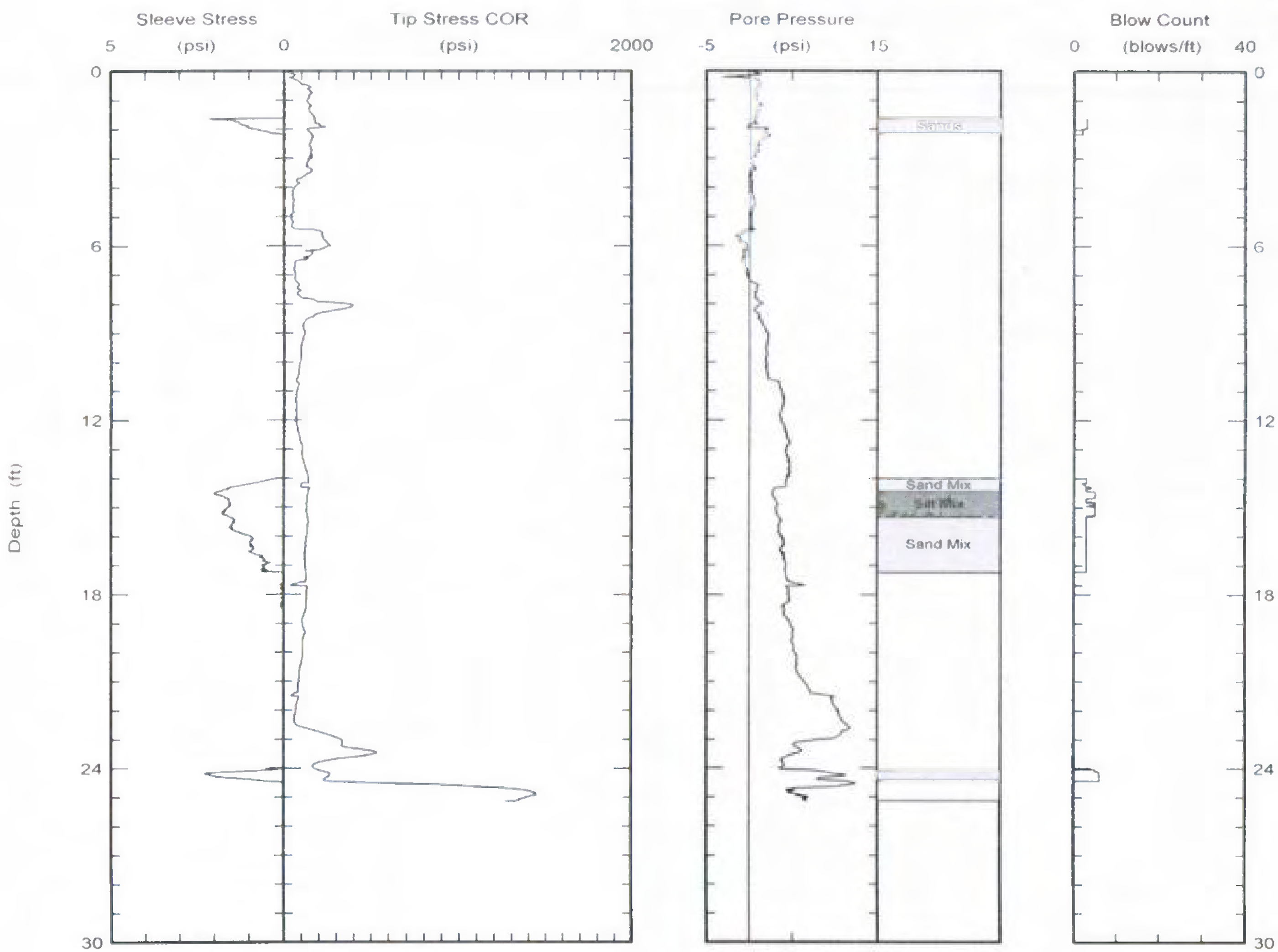


Maximum depth: 23.02 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt20
File: A16Y1102C.ECP

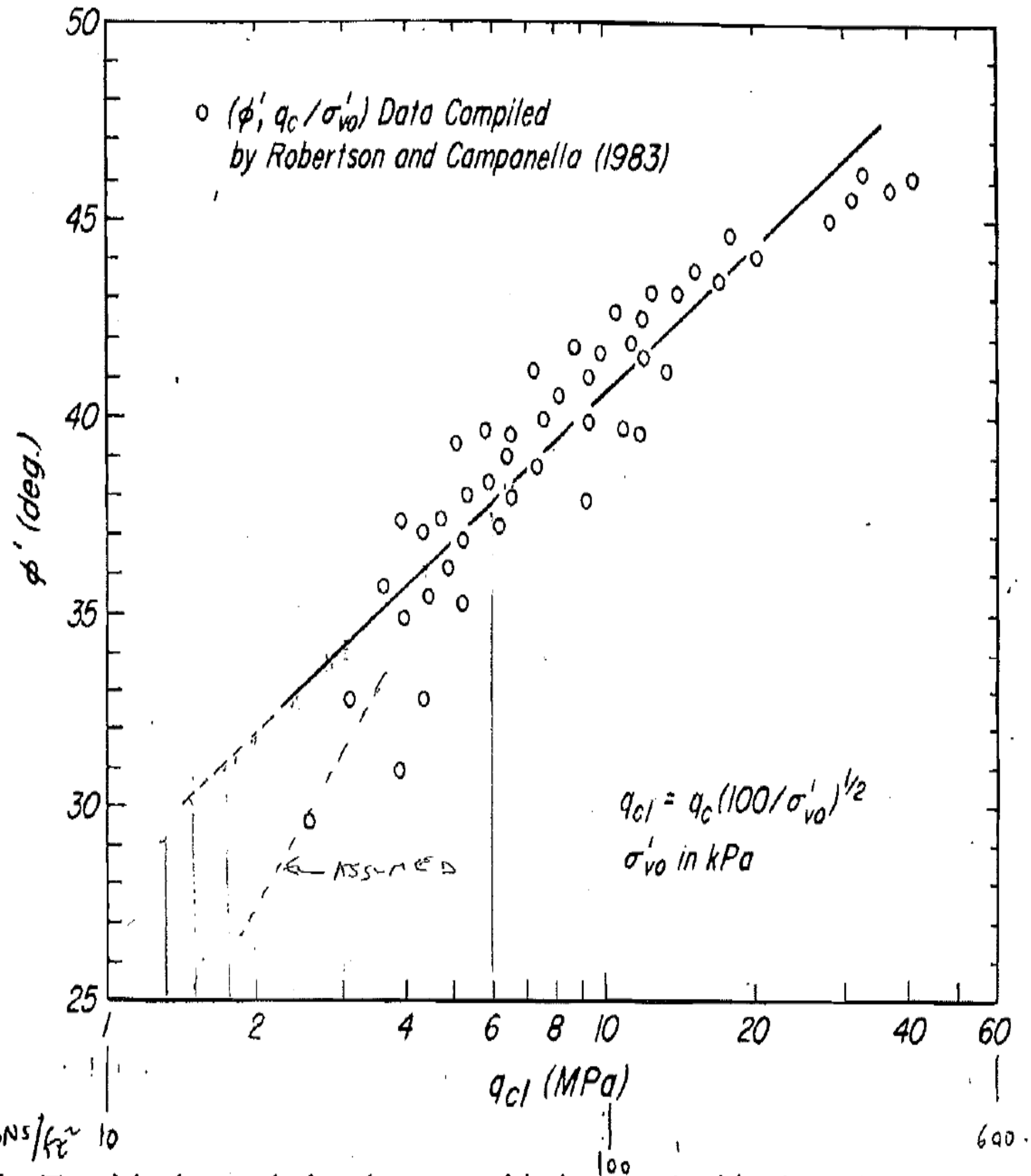
Applied Research Associates, Inc. South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Northing: Easting: Elevation:	Date: 16/May/2011 Test ID: cpt21 Project: Alliant
	Client: Aetherdbs Job Site: Burlington	



Maximum depth: 25.13 (ft)

11/25/2020 - Classification: Internal - ECRM7803923

Test ID: cpt21
File: A16Y1103C.ECP



19.5 Empirical correlation between friction angle ϕ' of sands and norma penetration resistance.

Re: TERZAGHI PECK & MESRI (1996), SOIL MECHANICS IN ENG. PRACTICE, 3RD ED., JOHN WILEY & SONS, INC

APPENDIX D – Laboratory Testing on CCR Embankment Soils

Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

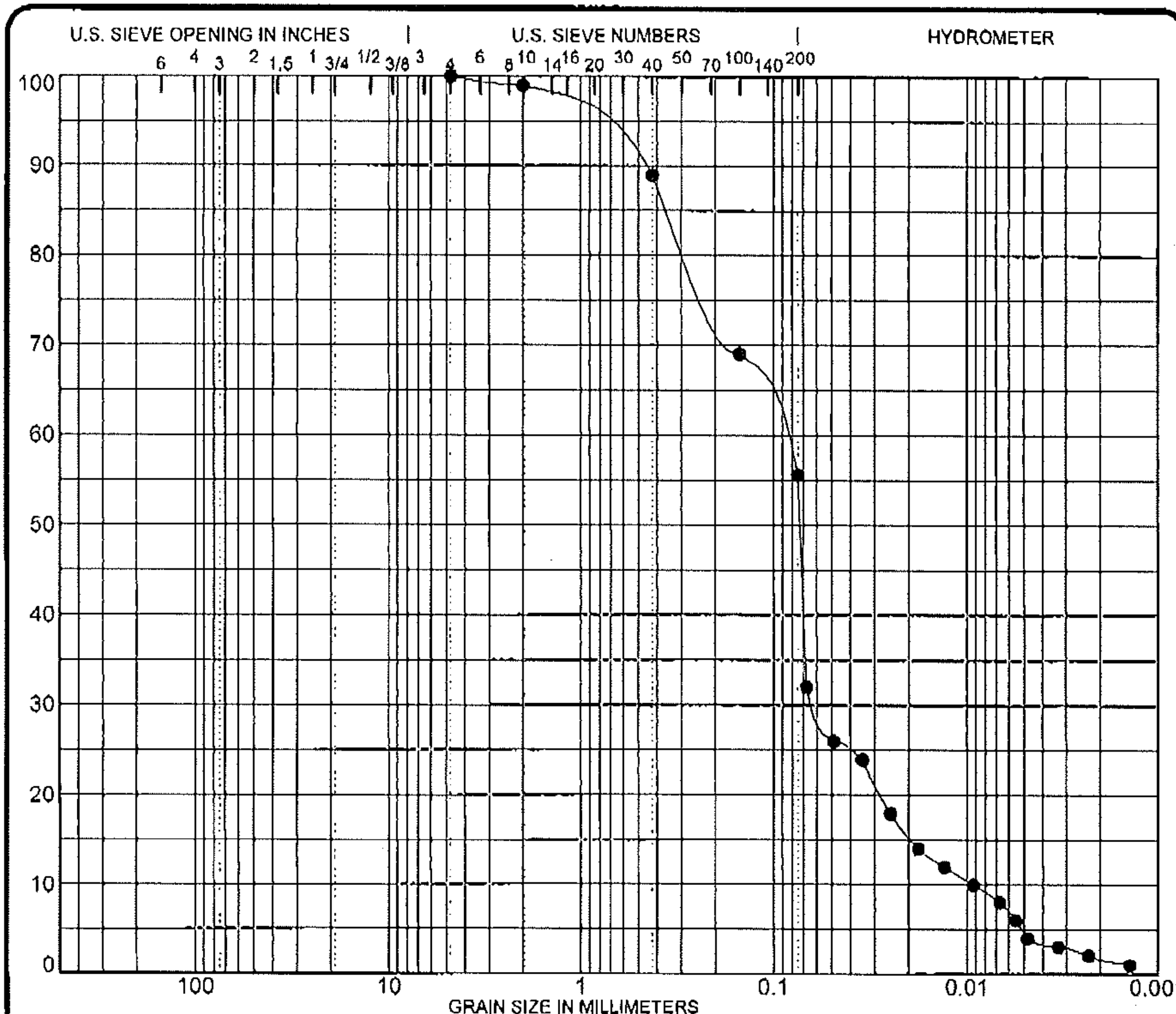
Safety Factor Assessment

Attachment C

Soil Laboratory Results

Burlington Generating Station

Source: Testing Service Corporation, May 2011



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Broing: SB-1	3 inch	100	Brown ASH			
Sample: Ash	2	100				
	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	44	54	2
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	99	44.0	NP	NP	NP
	# 40	89				
	# 100	69				
	# 200	56				

PROJECT Geotechnical Testing
LOCATION ,

JOB NO. L - 76,757
DATE May 20, 2011

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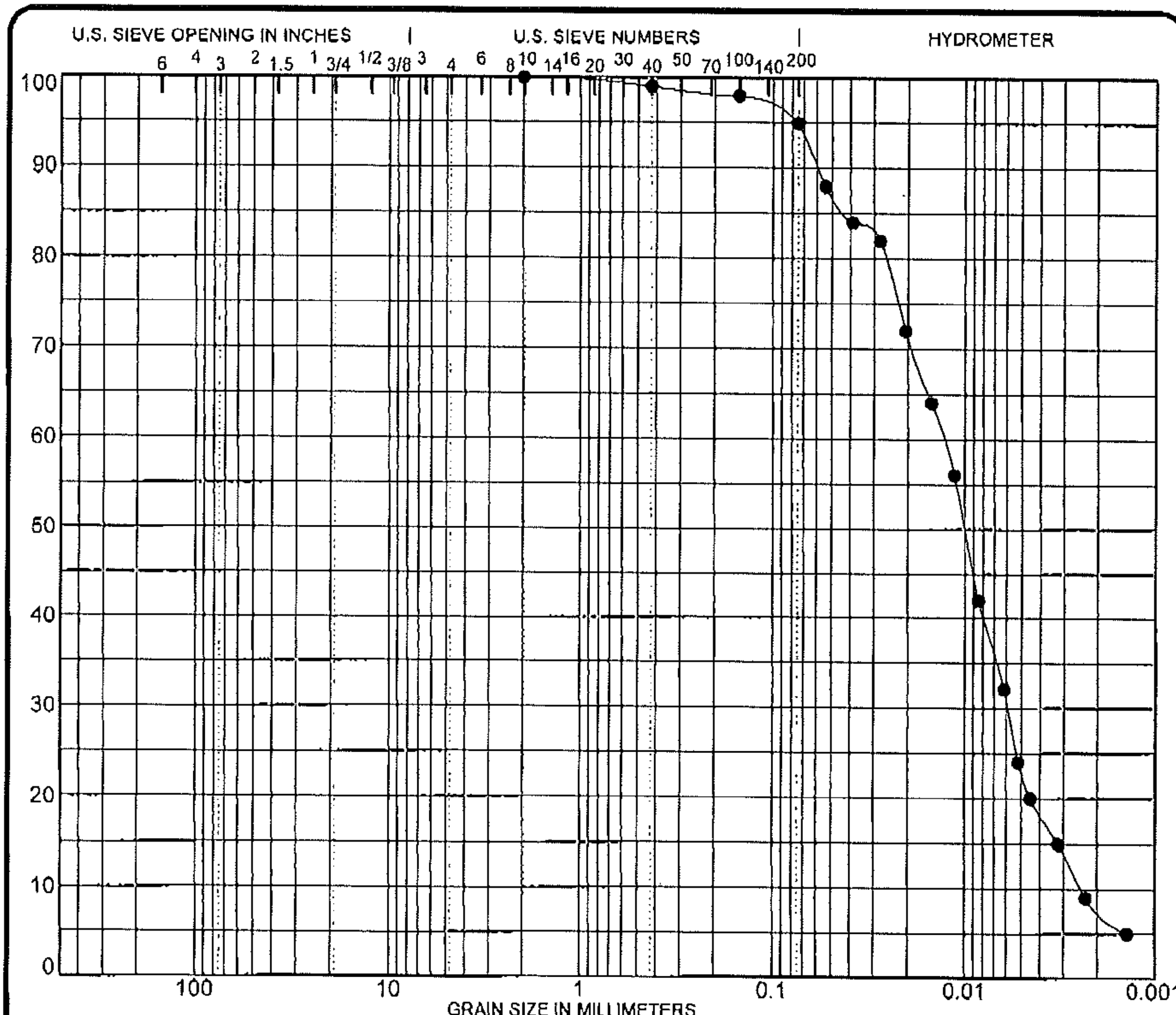
SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/20/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-1	3 inch	100	Gray clayey SILT, trace sand (ML)
Sample: A	2	100	
Depth: 25.0'-26.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	100	
	# 4	100	
	# 10	100	
	# 40	99	
	# 100	98	
	# 200	95	

%GRAVEL	%SAND	%SILT	%CLAY
0	5	87	8

MC%		LL	PL	PI
69.4		36	31	5

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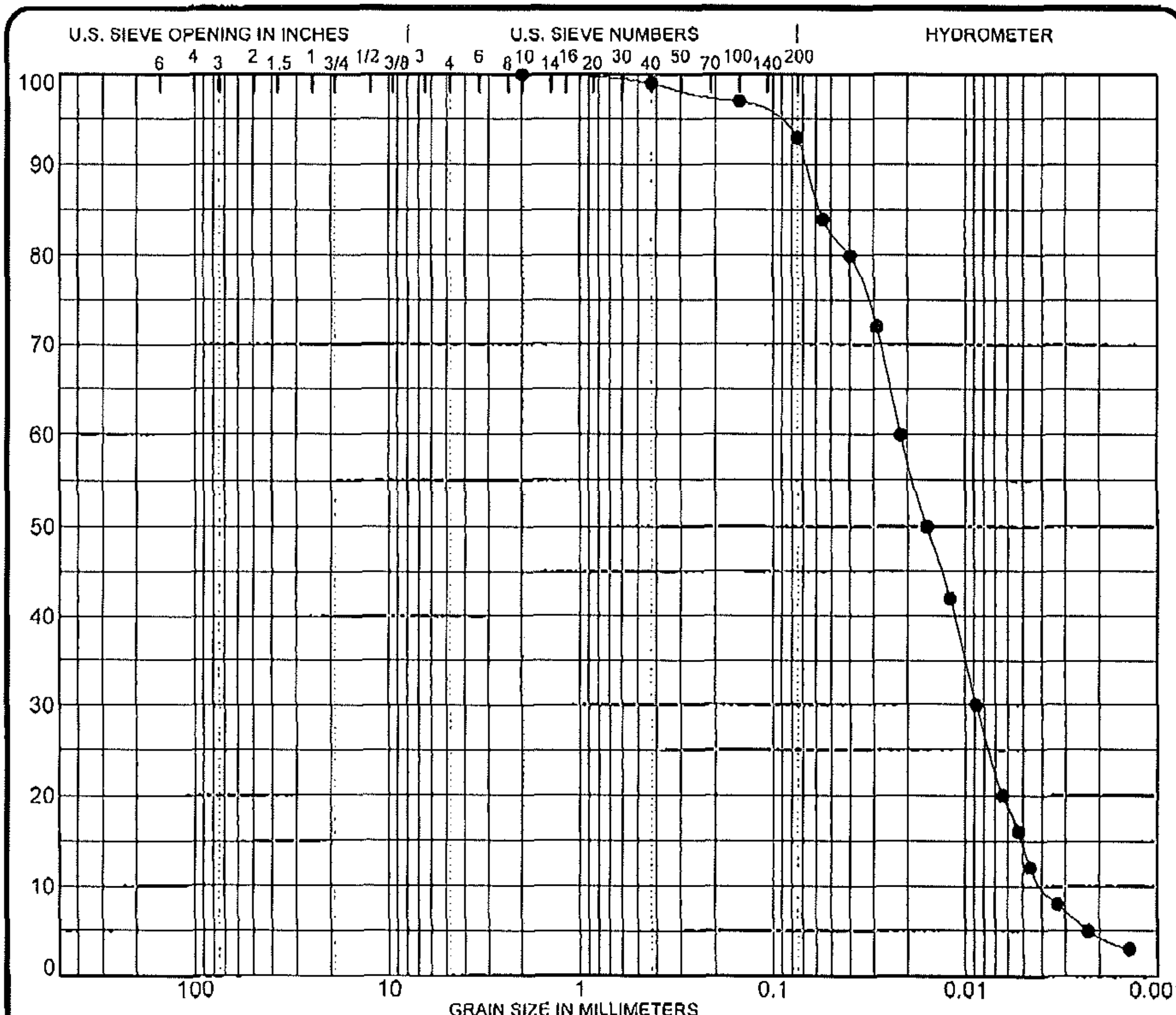
05/20/2011 11:18 FAX



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-1	3 inch	100	Gray clayey SILT, trace sand (ML)			
Sample: 8	2	100				
Depth: 29.0'-30.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	7	89	4
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	100	58.6	40	37	3
	# 40	99				
	# 100	97				
	# 200	93				

PROJECT Geotechnical Testing
LOCATION ,
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DATE May 20, 2011

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Carol Stream, IL 60188

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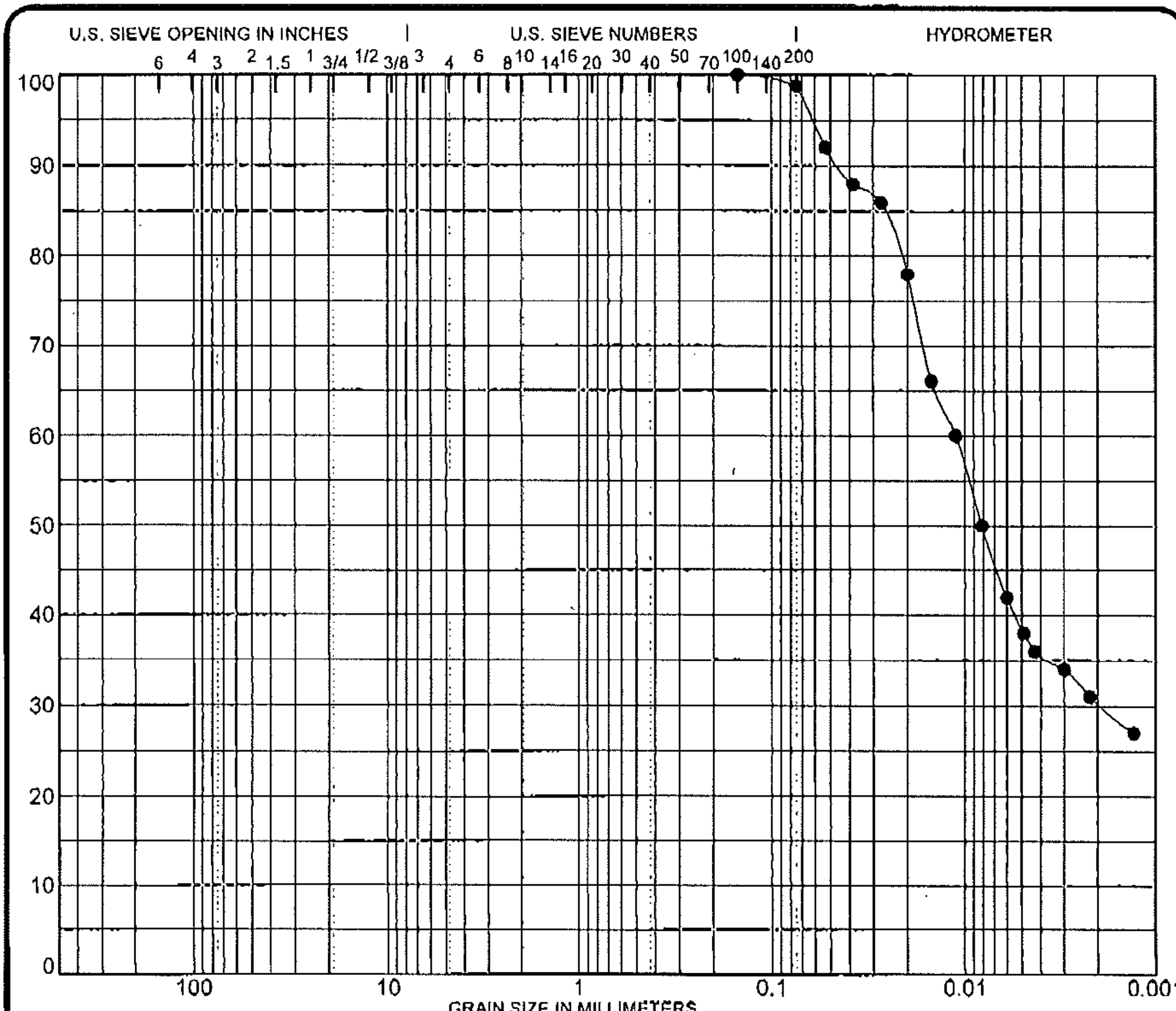

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-1	3 inch	100	Gray silty CLAY, trace sand (CH)
Sample: C	2	100	
Depth: 34.0'-35.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	100	
	# 4	100	
	# 10	100	
	# 40	100	
	# 100	100	
	# 200	99	

%GRAVEL	%SAND	%SILT	%CLAY
0	1	69	30

MC%		LL	PL	PI
31.3		52	17	35

PROJECT Geotechnical Testing
LOCATION ,
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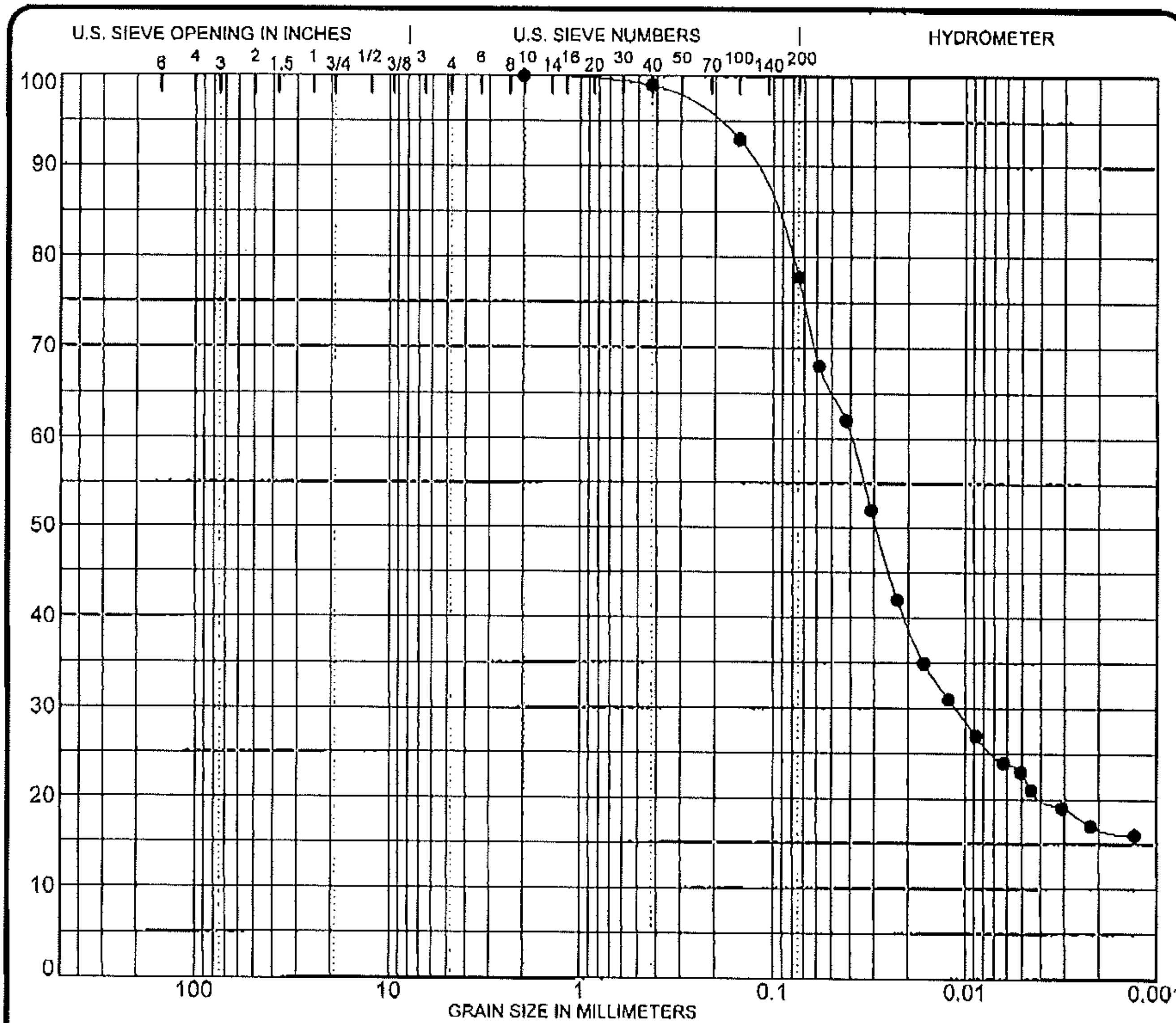

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-1	3 inch	100	Gray very silty CLAY, some sand (CL)
Sample: D	2	100	
Depth: 36.0'-37.0'	1 1/2	100	
	1	100	%GRAVEL: 0; %SAND: 22; %SILT: 61; %CLAY: 17
NOTES:	3/4	100	
	3/8	100	
	# 4	100	MC%: 29.1; LL: 36; PL: 16; PI: 20
	# 10	100	
	# 40	99	
	# 100	93	
	# 200	78	

%GRAVEL	%SAND	%SILT	%CLAY
0	22	61	17

MC%		LL	PL	PI
29.1		36	16	20

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DATE May 20, 2011

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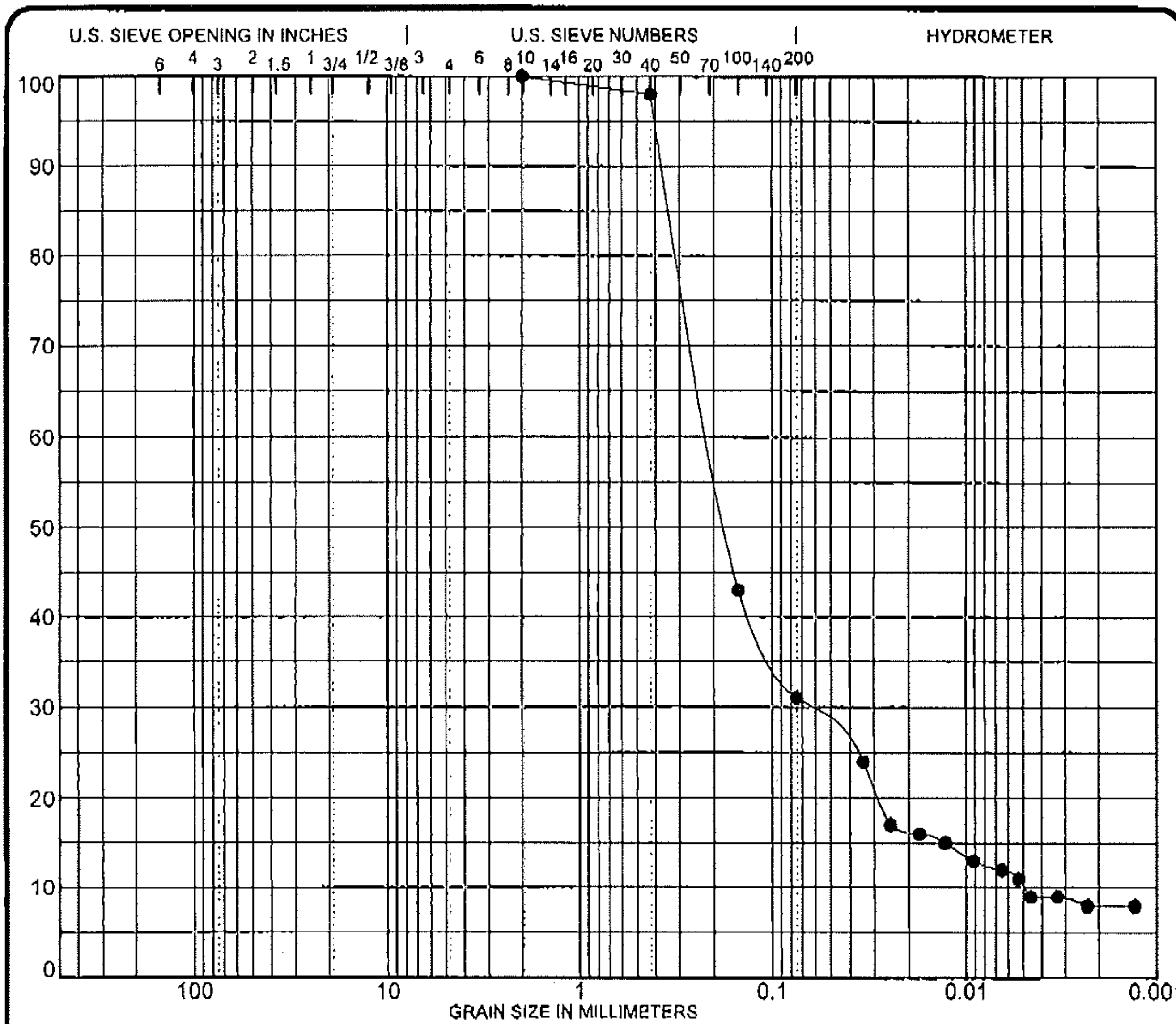

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-1	3 inch	100	Gray clayey SAND (SC)
Sample: E	2	100	
Depth: 37.0'-38.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	100	
	# 4	100	
	# 10	100	
	# 40	98	
	# 100	43	
	# 200	31	

%GRAVEL	%SAND	%SILT	%CLAY
0	69	23	8

MC%		LL	PL	PI
30.4		22	14	8

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LOCATION ,

JOB NO. L - 76,757
DATE May 20, 2011

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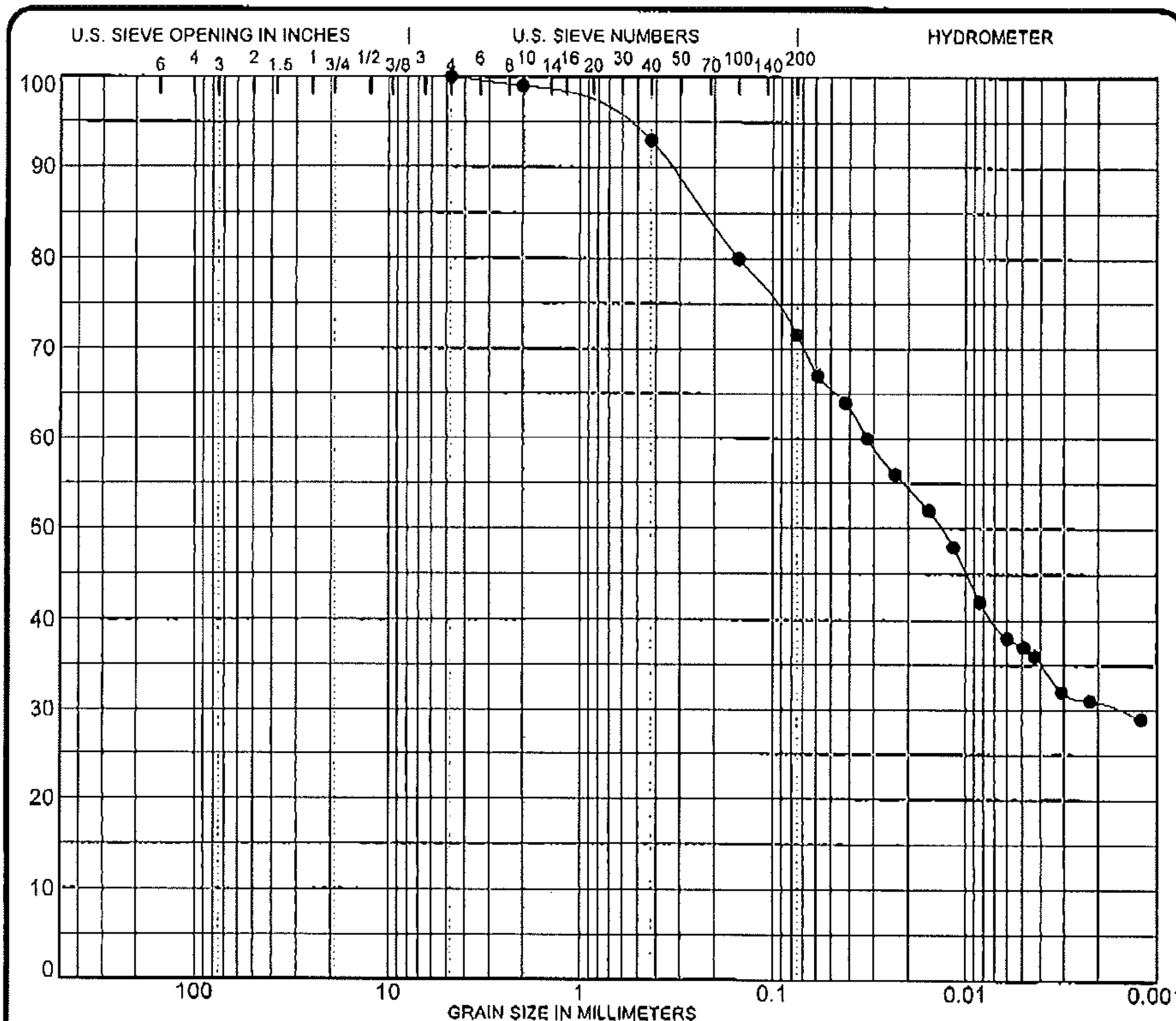
Testing Service Corporation
Carol Stream, IL 60188



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-2	3 inch	100	Brownish gray silty CLAY, some sand
Sample: A	2	100	(CL)
Depth: 8.0'-9.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	100	
	# 4	100	
	# 10	99	
	# 40	93	
	# 100	80	
	# 200	72	

%GRAVEL	%SAND	%SILT	%CLAY
0	28	41	31

MC%		LL	PL	PI
15.7		46	12	34

PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 20, 2011

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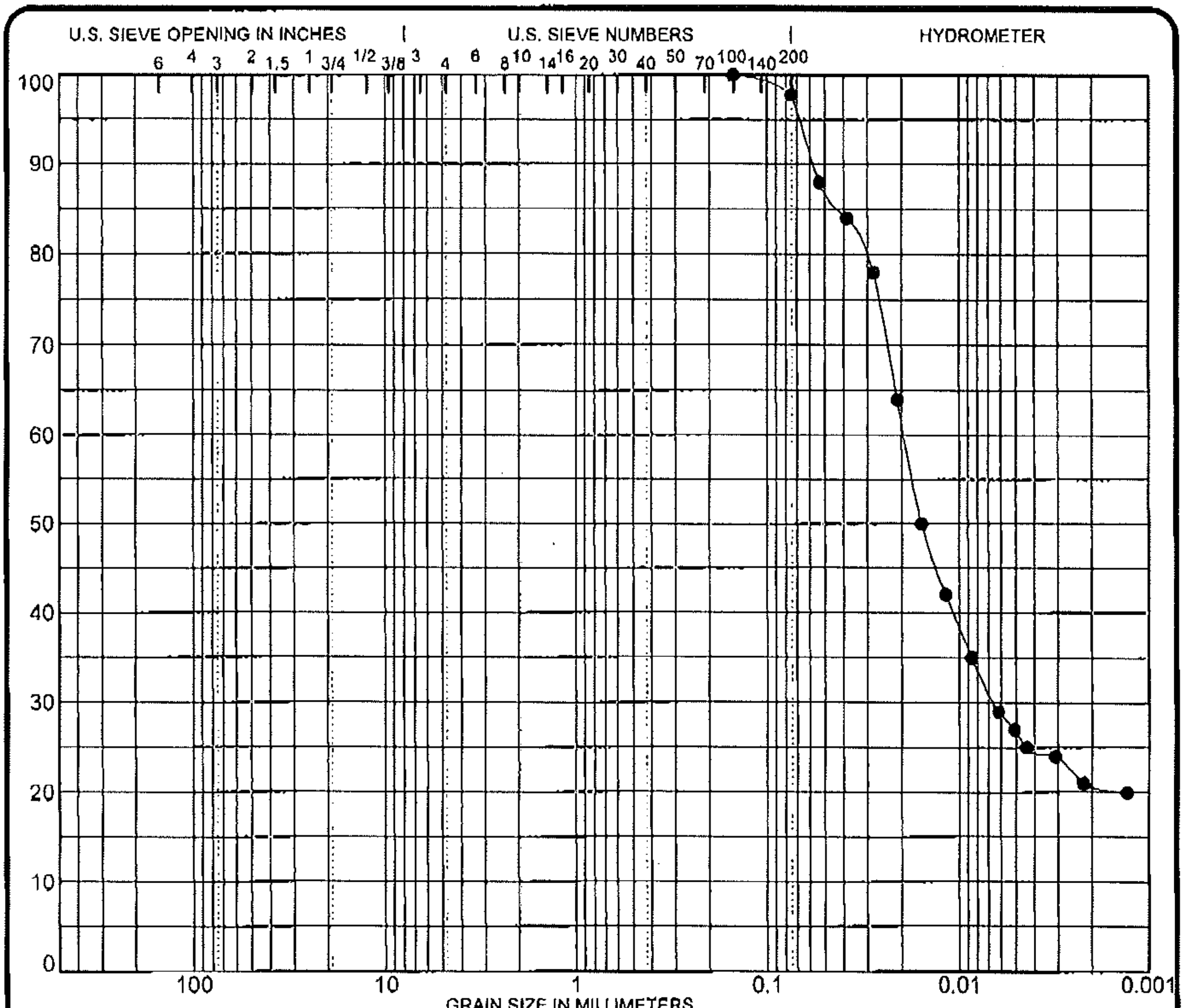
SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC ALL.GDT 5/20/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-2	3 inch	100	Dark gray very silty CLAY, trace sand
Sample: B	2	100	(CL)
Depth: 28.0'-29.0	1 1/2	100	
	1	100	%GRAVEL: 0 / %SAND: 2 / %SILT: 77 / %CLAY: 21
NOTES:	3/4	100	
	3/8	100	
	# 4	100	MC%: 35.1 / LL: 42 / PL: 18 / PI: 24
	# 10	100	
	# 40	100	
	# 100	100	
	# 200	98	

%GRAVEL	%SAND	%SILT	%CLAY
0	2	77	21

MC%		LL	PL	PI
35.1		42	18	24

PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 20, 2011

SB2

SOIL DATA SHEET

Testing Service Corporation
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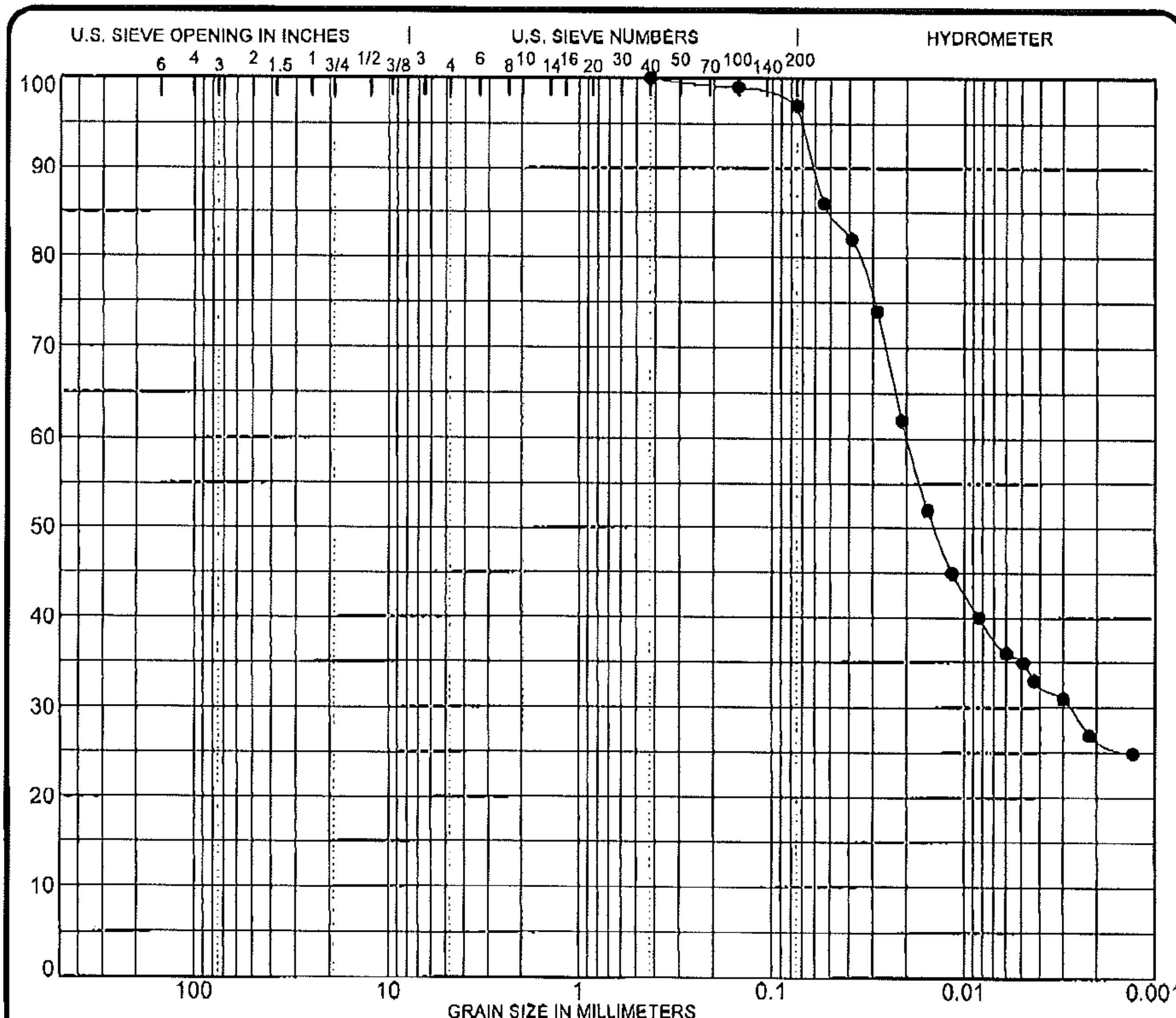
SOILGENR 76757.GPJ TSC_ALL.GDT 5/20/11

11/25/2020 - Classification: Internal - ECRM7803923

05/20/2011 11:40 FAX



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS
Boring: SB-2	3 inch	100
Sample: C	2	100
Depth: 32.0'	1 1/2	100
	1	100
NOTES:	3/4	100
	3/8	100
	# 4	100
	# 10	100
	# 40	100
	# 100	99
	# 200	97

SOIL CLASSIFICATION

Dark gray silty CLAY, trace sand (CH)

%GRAVEL	%SAND	%SILT	%CLAY
0	3	70	27

MC%		LL	PL	PI
32.9		51	16	35

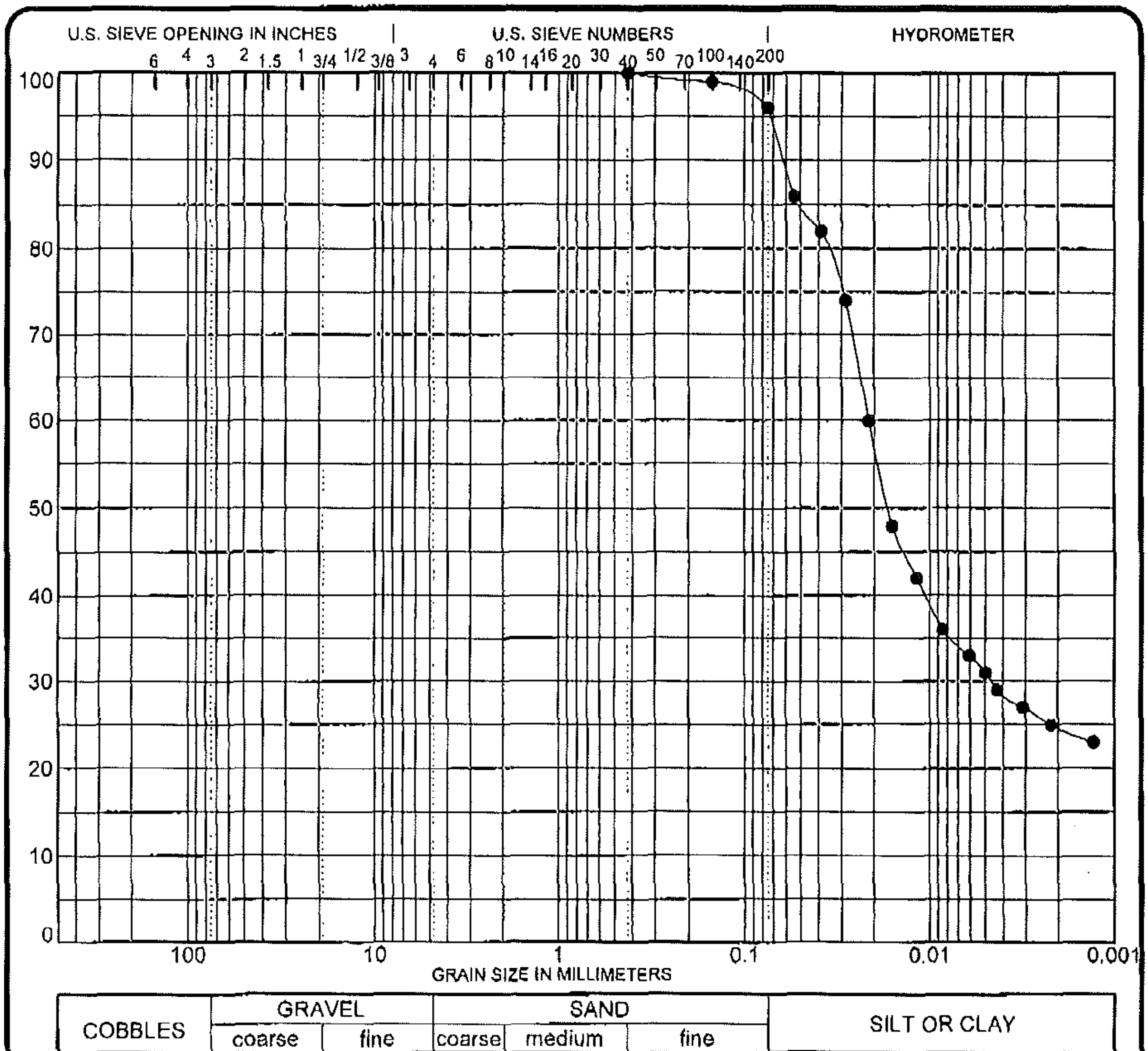
PROJECT Geotechnical Testing
LOCATION ,
SB2

JOB NO. L - 76,757
DATE May 20, 2011

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/20/11



SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-3	3 inch	100	Dark gray very silty CLAY, trace sand
Sample: A	2	100	(CL)
Depth: 38.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	100	
	# 4	100	
	# 10	100	
	# 40	100	
	# 100	99	
	# 200	96	

%GRAVEL	%SAND	%SILT	%CLAY
0	4	71	25

MC%		LL	PL	PI
34.4		46	15	31

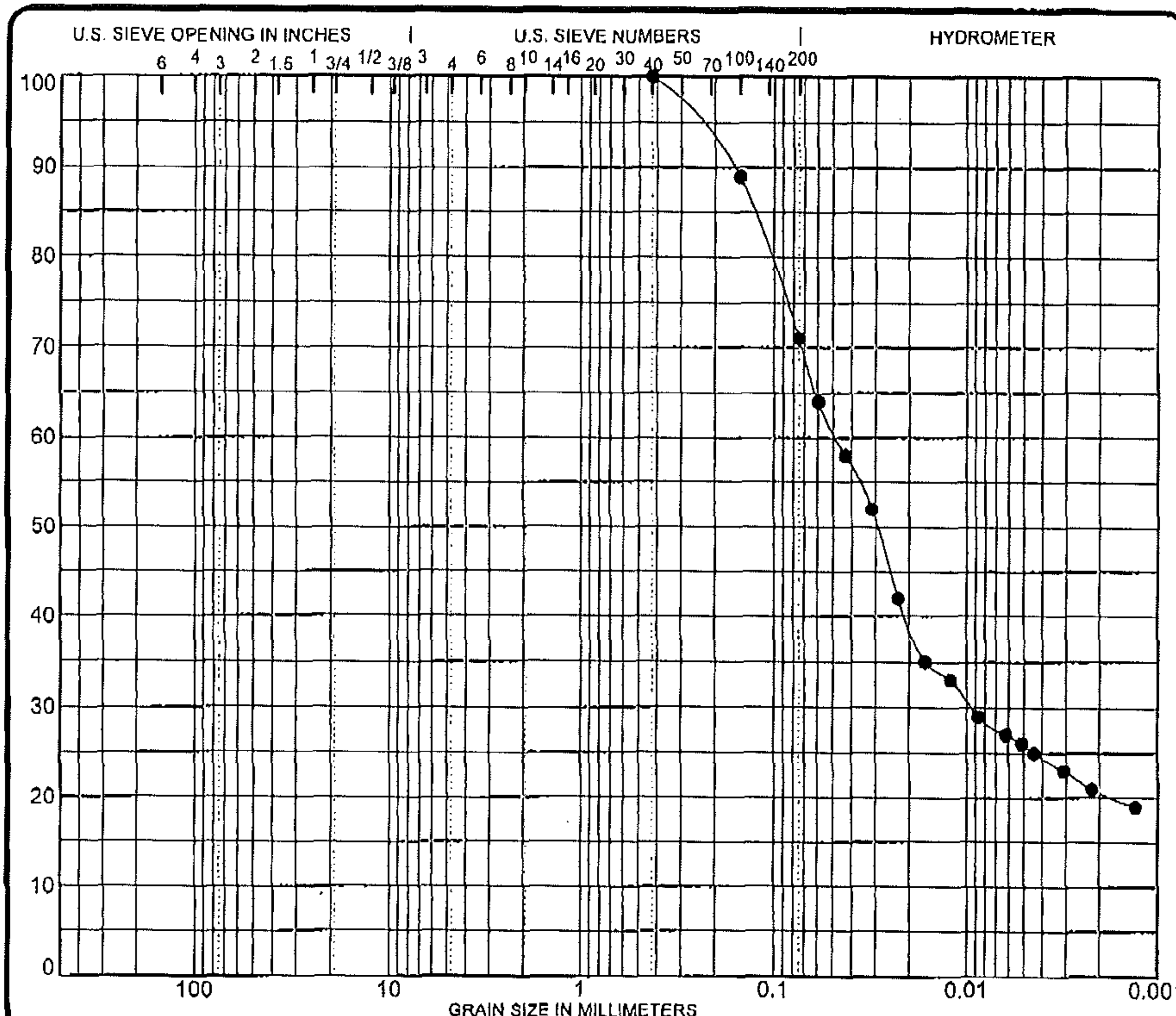
PROJECT Geotechnical Testing
LOCATION ,

JOB NO. L - 76,757
DATE May 20, 2011

SB3

SOILGENR 76757.GPJ TSC_ALL.GDT 5/20/11

SOIL DATA SHEET
Testing Service Corporation
Carol Stream, IL 60188



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-4	3 inch	100	Dark gray silty CLAY, some sand (CL)			
Sample: A	2	100				
Depth: 34.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	29	50	21
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	100	24.1	41	12	29
	# 40	100				
	# 100	89				
	# 200	71				

PROJECT Geotechnical Testing
LOCATION ,

JOB NO. L - 76,757
DATE May 20, 2011

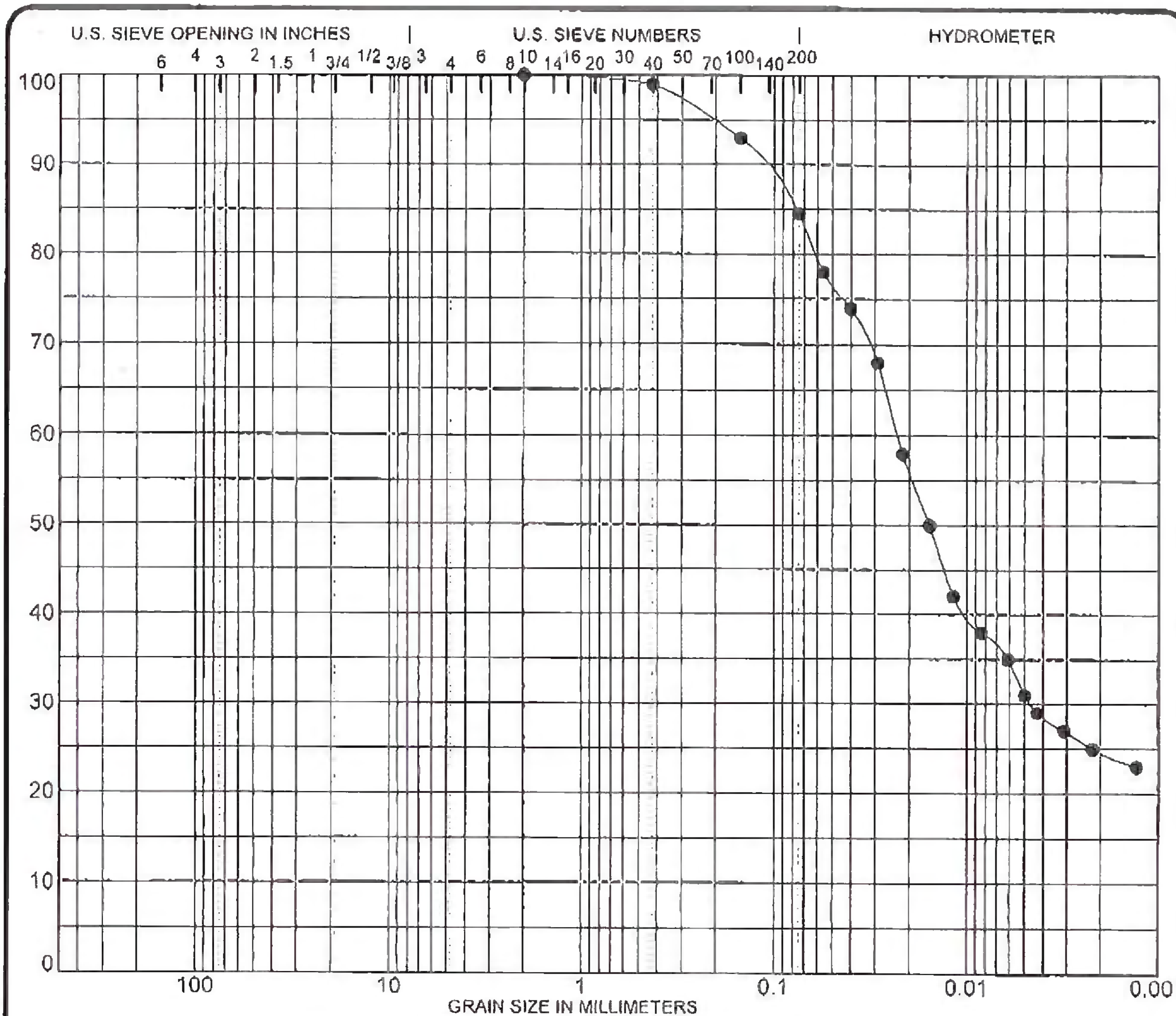
SB4

SOILGENR 76757.GPJ TSC ALL.GDT 5/20/11

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

06/20/2011 11:50 FAX
012



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS
Boring: SB-5	3 inch	100
Sample: A	2	100
Depth: 34.0'	1 1/2	100
	1	100
NOTES:	3/4	100
	3/8	100
	# 4	100
	# 10	100
	# 40	99
	# 100	93
	# 200	85

SOIL CLASSIFICATION

Gray very silty CLAY, little sand (CL)

%GRAVEL	%SAND	%SILT	%CLAY
0	15	60	25

MC%		LL	PL	PI
23.3		43	16	27

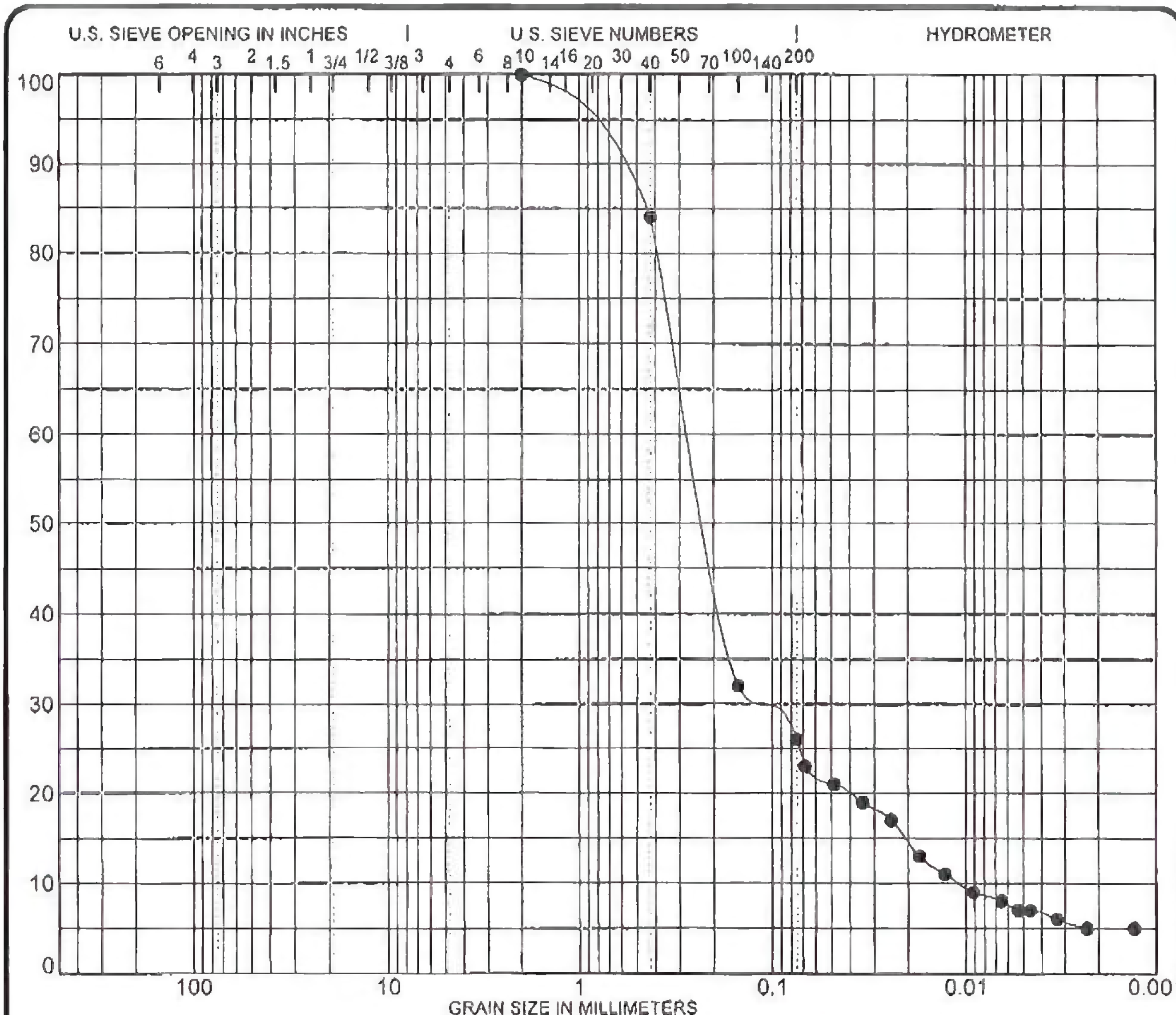
PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 23, 2011

SB5

SOILGENR 76757.GPJ TSC AL1.GDT 5/23/11

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-6	3 inch	100	Gray clayey SAND (SC)			
Sample: A	2	100				
Depth: 16.0'-17.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	74	21	5
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	100	24.6	16	13	3
	# 40	84				
	# 100	32				
	# 200	26				

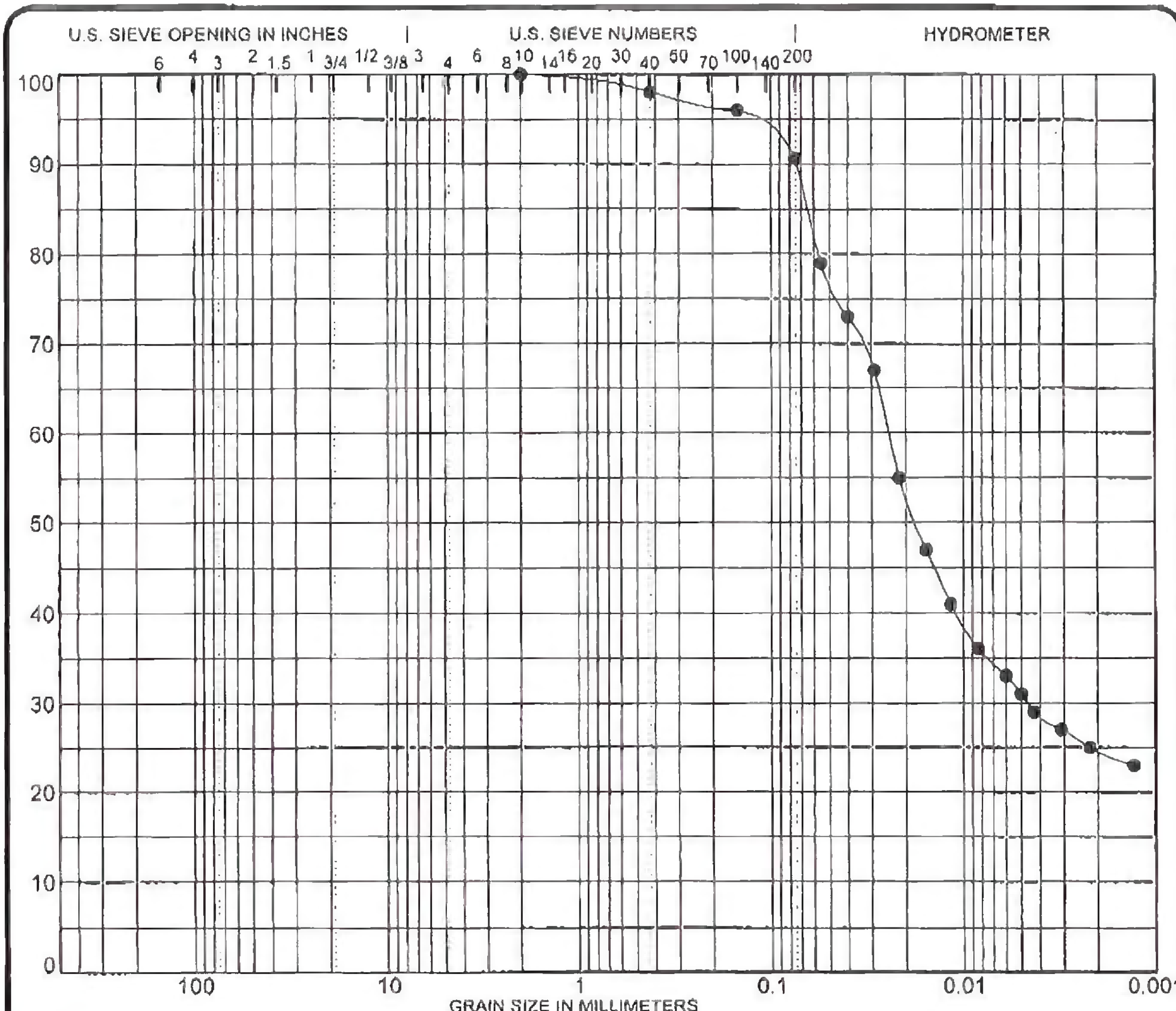
PROJECT **Geotechnical Testing**
LOCATION ,
JOB NO. **L - 76,757**
DATE **May 23, 2011**

SB6

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC ALL.GDT 5/23/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-6	3 inch	100	Brownish gray very silty CLAY, trace sand			
Sample: B	2	100	(CL)			
Depth: 28.0'-29.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	9	66	25
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	100	28.3	43	13	30
	# 40	98				
	# 100	96				
	# 200	91				

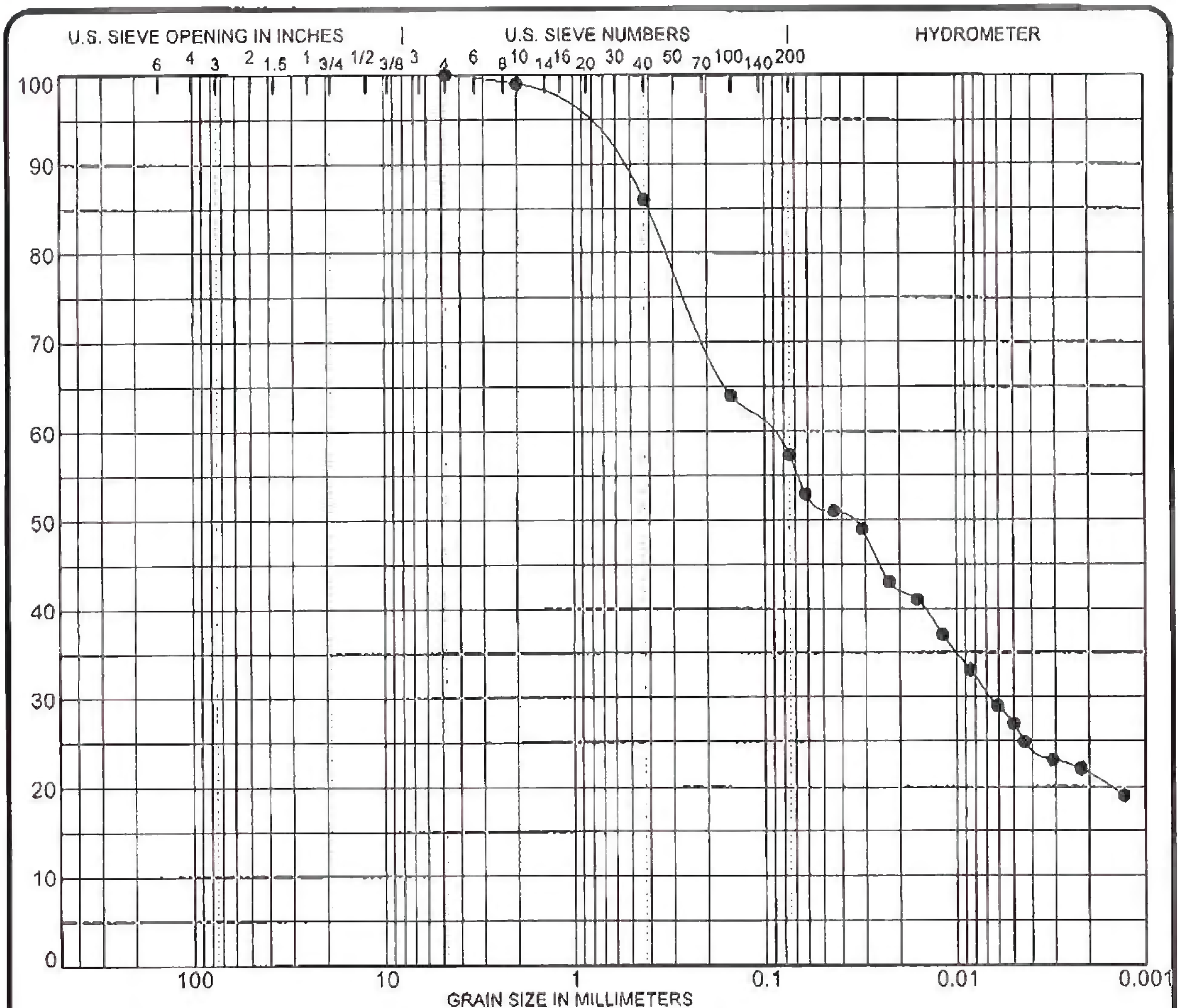
PROJECT Geotechnical Testing
LOCATION ,

JOB NO. L - 76,757
DATE May 23, 2011

SB6

SOIL DATA SHEET
Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/23/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-8	3 inch	100	Gray sandy CLAY (CL)			
Sample: A	2	100				
Depth: 10.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	43	36	21
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	99	21.6	36	12	24
	# 40	86				
	# 100	64				
	# 200	57				

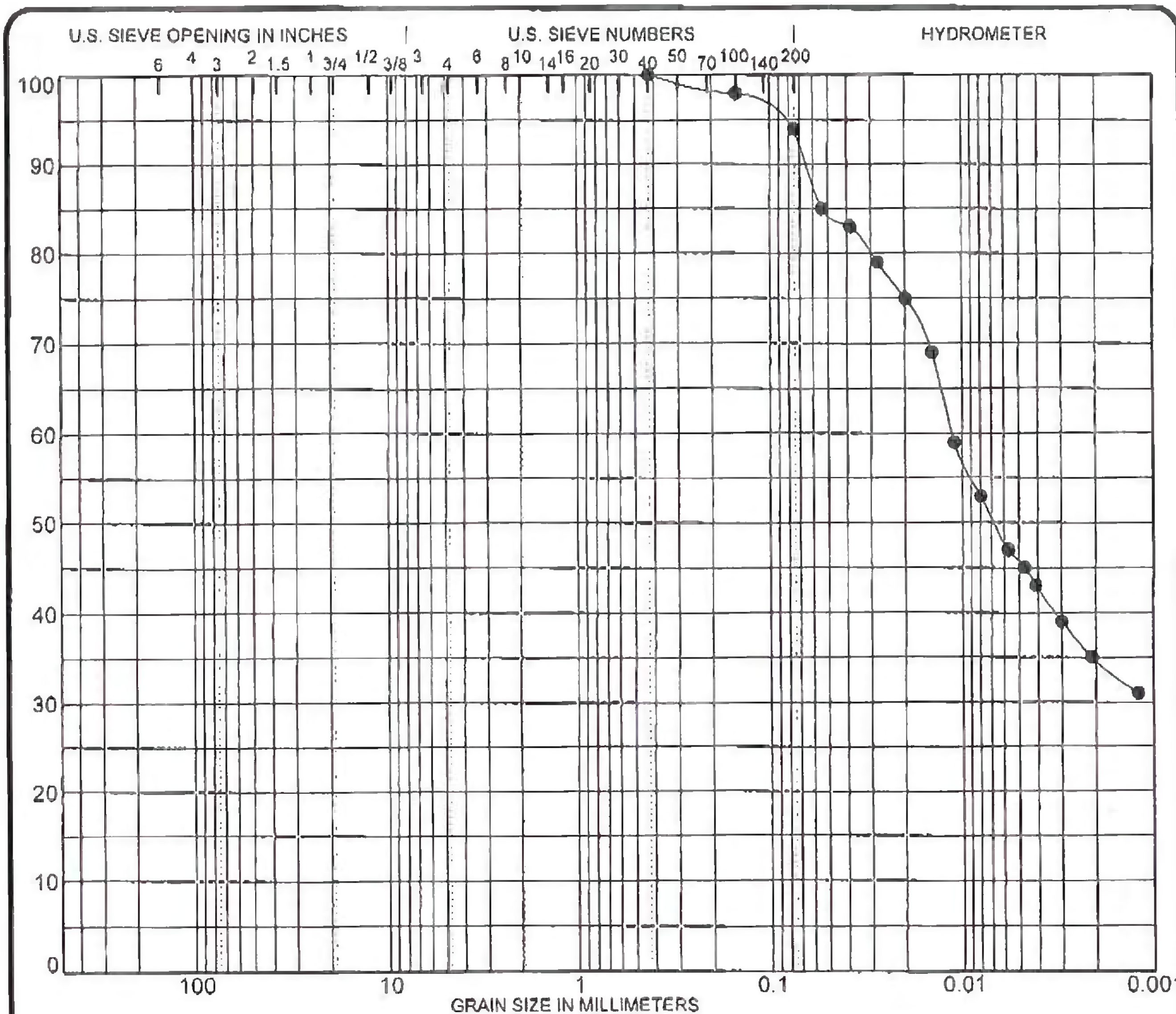
PROJECT Geotechnical Testing
LOCATION ,
SB8

JOB NO. L - 76,757
DATE May 23, 2011

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/23/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-8	3 inch	100	Gray very silty CLAY, trace sand (CL)			
Sample: B	2	100				
Depth: 20.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	6	59	35
	3/8	100				
	# 4	100	MC%		LL	PL	PI
	# 10	100	31.1		56	19	37
	# 40	100				
	# 100	98				
	# 200	94				

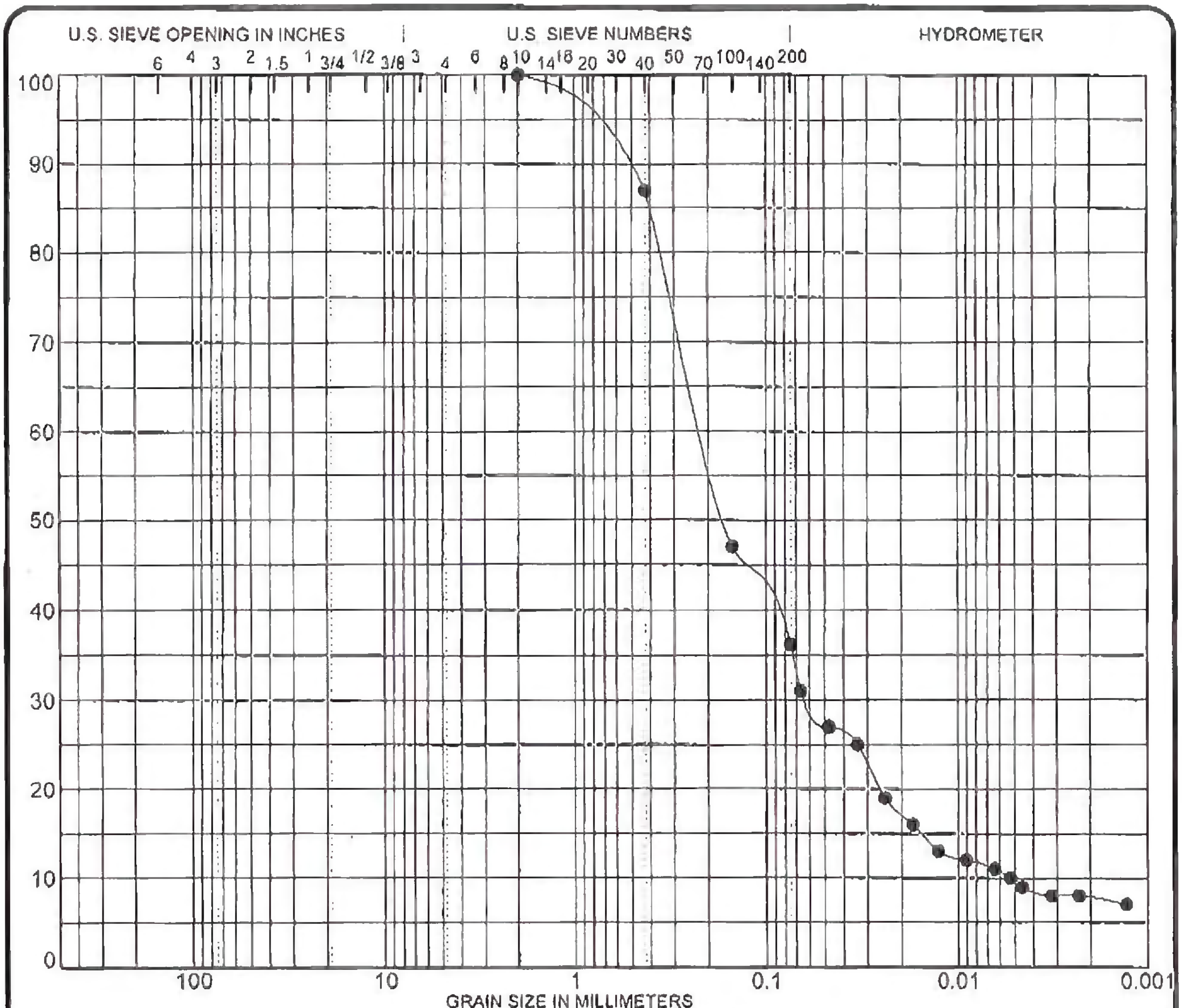
PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 23, 2011

SB8

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC ALL.GDT 5/23/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-8	3 inch	100	Gray clayey SAND (SC)
Sample: C	2	100	
Depth: 22.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	100	
	# 4	100	
	# 10	100	
	# 40	87	
	# 100	47	
	# 200	36	

%GRAVEL	%SAND	%SILT	%CLAY
0	64	28	8

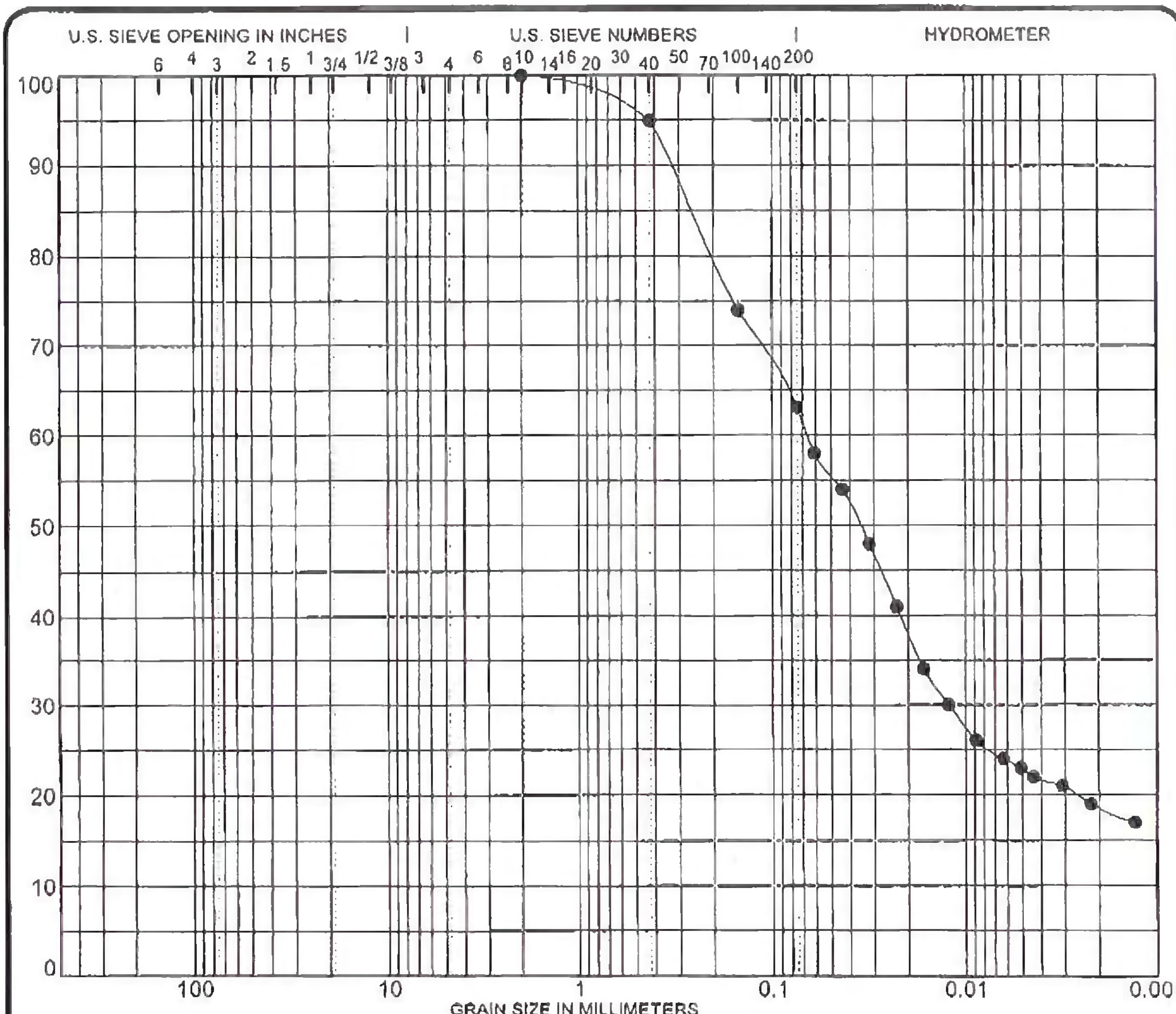
MC%		LL	PL	PI
26.9		21	13	8

PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 23, 2011

SBB

SOIL DATA SHEET
Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/23/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION			
Boring: SB-9	3 inch	100	Brownish gray sandy CLAY (CL)			
Sample: A	2	100				
Depth: 18.0'	1 1/2	100				
	1	100	%GRAVEL	%SAND	%SILT	%CLAY
NOTES:	3/4	100	0	37	44	19
	3/8	100				
	# 4	100	MC%	LL	PL	PI
	# 10	100	34.0	35	13	22
	# 40	95				
	# 100	74				
	# 200	63				

PROJECT Geotechnical Testing
LOCATION ,

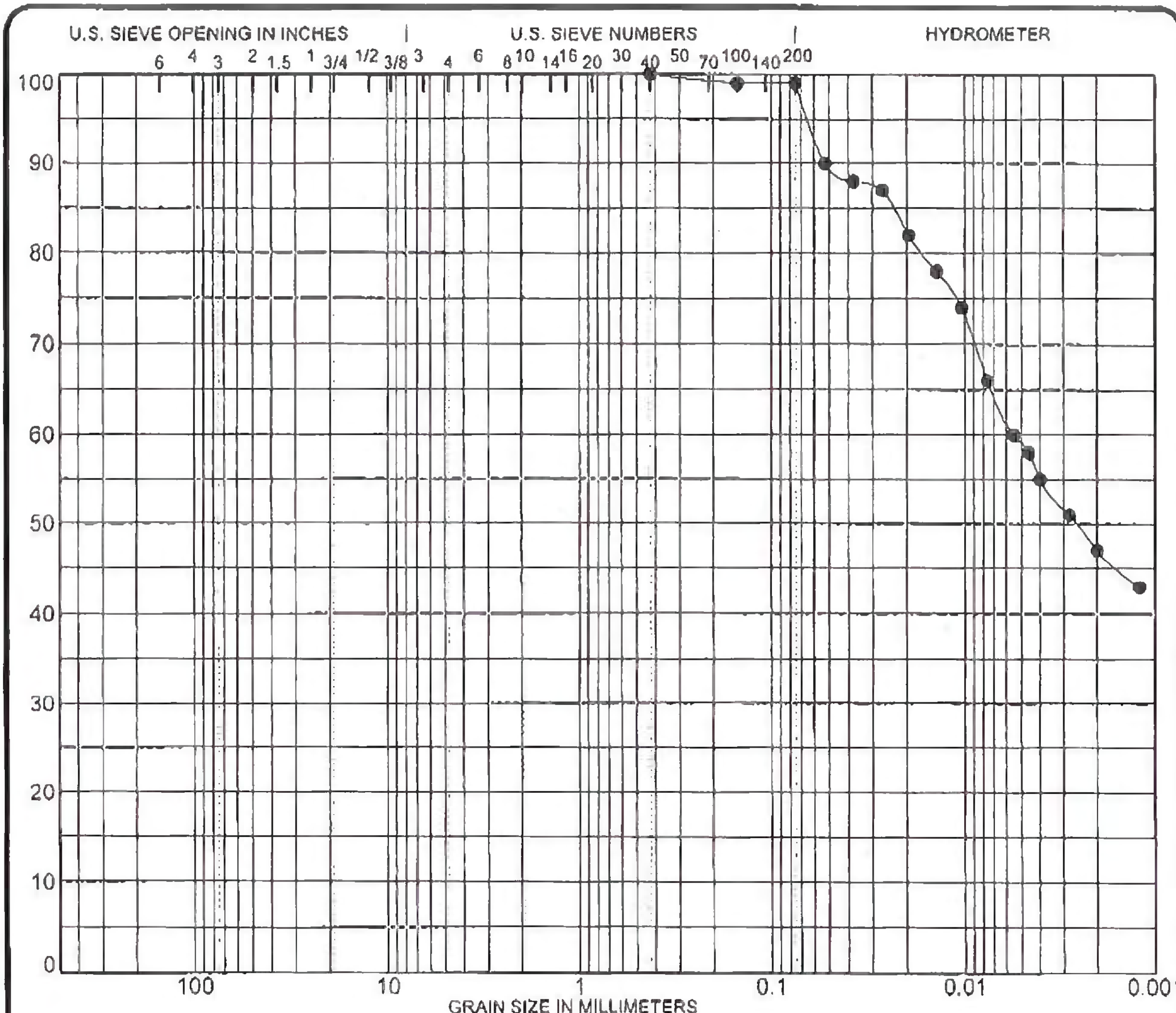
JOB NO. L - 76,757
DATE May 23, 2011

SB9

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/23/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS
Boring: SB-10	3 inch	100
Sample: A	2	100
Depth: 20.0'	1 1/2	100
	1	100
NOTES:	3/4	100
	3/8	100
	# 4	100
	# 10	100
	# 40	100
	# 100	99
	# 200	99

SOIL CLASSIFICATION

Brownish gray silty CLAY, trace sand
(CH)

%GRAVEL	%SAND	%SILT	%CLAY
0	1	52	47

MC%		LL	PL	PI
26.9		74	15	59

PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 23, 2011

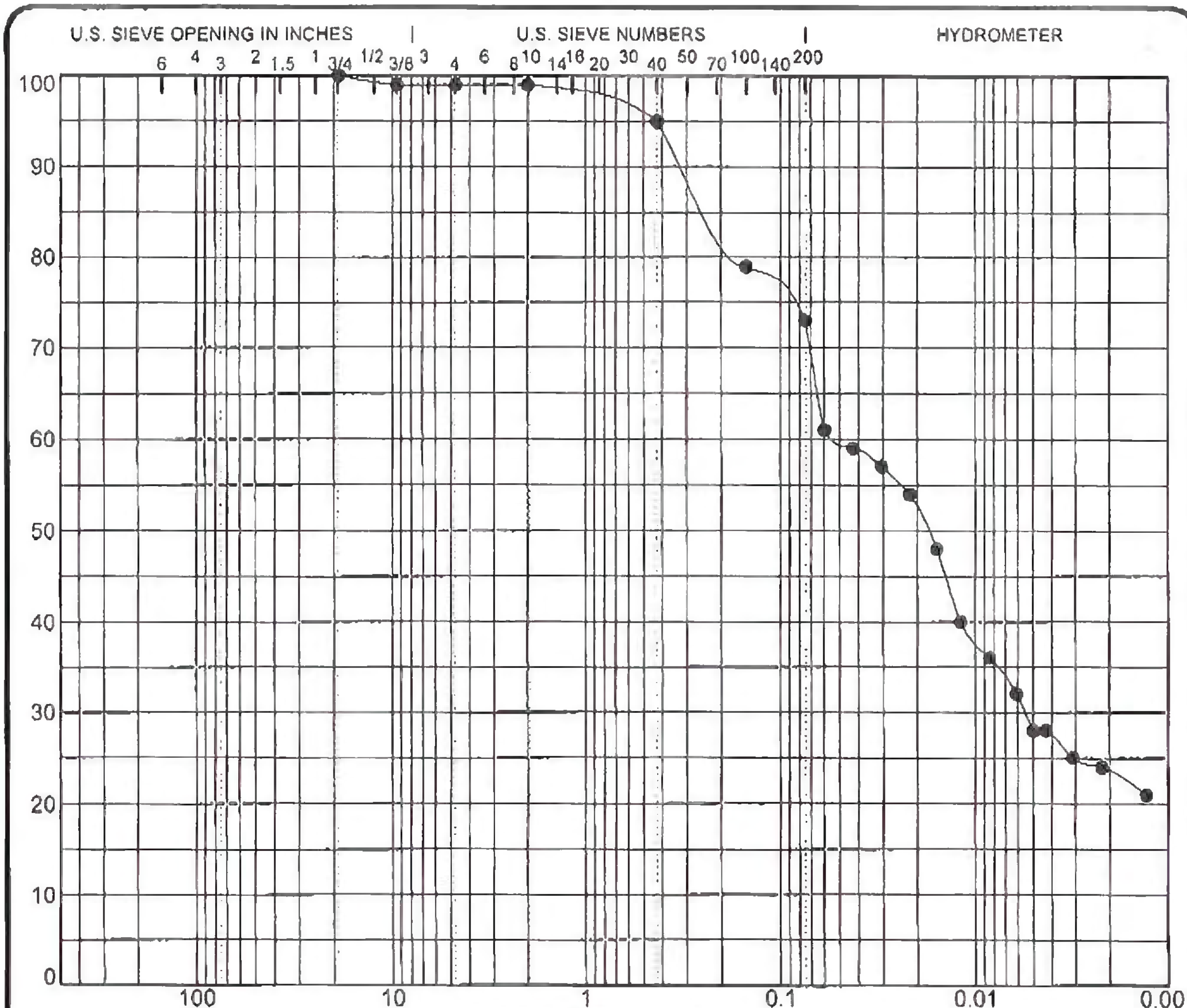
SB10

SOIL DATA SHEET
Testing Service Corporation
Carol Stream, IL 60188

SOILGENR 76757.GPJ TSC_ALL.GDT 5/23/11

11/25/2020 - Classification: Internal - ECRM7803923

05/23/2011 13:57 FAX



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

SPECIMEN IDENTIFICATION	SIEVE	% PASS	SOIL CLASSIFICATION
Boring: SB-12	3 inch	100	Gray silty CLAY, some sand, trace gravel
Sample: A	2	100	(CL)
Depth: 23.0'-24.0'	1 1/2	100	
	1	100	
NOTES:	3/4	100	
	3/8	99	
	# 4	99	
	# 10	99	
	# 40	95	
	# 100	79	
	# 200	73	

%GRAVEL	%SAND	%SILT	%CLAY
1	26	50	23

MC%		LL	PL	PI
35.9		42	16	26

PROJECT Geotechnical Testing
LOCATION ,
JOB NO. L - 76,757
DATE May 23, 2011

SB12

SOILGENR 76757.GPJ TSC ALL.GDT 5/23/11

SOIL DATA SHEET

Testing Service Corporation
Carol Stream, IL 60188

APPENDIX E – Earthquake and Liquefaction Analysis

Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

Safety Factor Assessment

IPL Burlington Generating Station
Generalized Soil Profile

Soils Data for the Burlington Generating Station Includes the following information:

1. Nine soil borings installed in 1962 by Raymond Drilling for design of the foundations of the power plant
2. Ten soil borings installed by RDnP in 2008 for planning of air pollution control equipment installation in Ash Seal Pond area near plant
3. Twelve soil borings and CPT probes from May 2011

a. The borings for #1 and #2 are focused on the area of the power plant and extend to refusal on or near the bedrock surface of the river valley.
b. The borings for #1 and #2 include measurement of soil density by standard split spoon blowcount.
c. The borings of #3 are focused on the embankments of the CCR ponds and the underlying soft clay terminating at the surface of the medium dense sand found in the borings of #1 and #3
d. The borings of #3 for the economizer pond measure the strength and liquefaction potential of the fly ash using a cone penetrometer.

Generalized Soil Profile Based on Soil Boring Information

	Contact Elevation						
	Ground	Ground Contact	Soft Clay	Medium Dense Sand		Very Dense Sand	Rock
Ash Seal Pond	534	Clay	520	510		470	450
Main Ash Pond	534	Clay	520	510		470	450
Economizer Pond	548	Fly Ash	520	510		470	450
Upper Ash Pond	531	Clay	520	510		470	450

Generalized Soil Profile Soil Strength/Density

	N	S_u (psf)	Source:
Very Dense Sand	70		Boring BH-B-1
Medium Dense Sand	25		Boring BH-B-1
Soft Clay		600	Embankment SB borings
Medium Stiff Clay		800	Embankment SB borings
CCR	6		CPT-1 Economizer Pond

Site Classification IBC 2009 Section 1613.5.5

Weight N_{ch} =	32 deep sands	Site Class D
Weighted s_u =	700 psf	Site Class E
N_{ccr} =	6	Site Class E

	Thickness (ft)		% of Class		Combined F_{pga}	Surface
	Class D	Class E	Class D	Class E		PGA
Clay Embankments	60	24	71%	29%	1.86	0.100
Economizer Pond	60	38	61%	39%	1.95	0.105

PGA Site Coefficient Table 11.8-1 for PGA<0.1 on bedrock
Bedrock PGA based on 2% probability in 50 Years USGS = 0.054 g

Site Class D = 1.6
Site Class E = 2.5

Simplified Seed and Idriss Liquefaction Analysis
CPT Based Analysis CPT1
Burlington Generating Station
Interstate Electric Power

Input Parameters:

Peak Ground Acceleration (g) = 0.105
Earthquake Magnitude, M = 7.7
Water Table Depth (m) = 6.1
Average Soil Density above water table (kN/m^3) = 18.0
Average Soil Density below water table (kN/m^3) = 19.0

Computed Constants:

Magnitude Scaling Factor = 0.95

Depth (m)	Tip $q_{cn\ (kPa)}$	$F_{sn\ (kPa)}$	σ_{vc} (kPa)	σ_{vc}' (kPa)	Q_t	F_r	I_c	Flag	Fines (%)	C_n	q_{c1N}	$q_{c1N\text{-}cs}$	r_D	CSR	k_σ for sand	CRR M=7.5 & 1 atm	CRR	Factor of Safety
0.75	54	0.6	14	14	403.0	1.11	1.53	U	10	1.70	91.6	104.4	1.00	0.068	1.10	0.150	n.a.	n.a.
2.25	12	0.2	41	41	28.9	1.72	2.48	U	10	1.70	19.7	27.3	0.99	0.068	1.05	0.060	n.a.	n.a.
3.75	32	0.26	68	68	46.9	0.83	2.13	U	10	1.32	41.5	50.6	0.98	0.067	1.03	0.078	n.a.	n.a.
5.25	32	0.59	95	95	33.2	1.90	2.46	U	50	1.06	32.8	74.7	0.96	0.066	1.01	0.106	n.a.	n.a.
6.75	32	0.39	122	116	26.9	1.27	2.43		80	0.89	27.5	66.9	0.95	0.068	0.99	0.096	0.090	1.32
8.25	15	0.39	151	130	10.5	2.89	2.97		80	0.78	10.5	44.1	0.93	0.074	0.98	0.072	0.067	0.91
9.75	10	0.19	179	143	5.8	2.31	3.14	Clay	1	0.70	n.a.	n.a.	0.91	0.078	0.89	n.a.	n.a.	n.a.

water pressures, so the dis
accompanied by densificat
available experimental da
for sands and silty sands i
would increase rapidly as
relationship can be repres

$$\frac{S_r}{\sigma'_{vo}} = \exp\left(\frac{(N_1)_{60c}}{16}\right.$$

$$\times \left(1 + \exp\right($$

IDRISS & BOULANGER
CHAPTER 4

$q_{c1N_{cs-S_r}} = 54$ kPa

$\sigma'_{vc} = 130$ kPa

$S_r/\sigma'_{vc} = 0.05$

$S_r = 0.05(130 \text{ kPa})$
$= 6.5$ kPa
$\simeq 100$ psf

The lower relations
in which the effects of
would include sites wit
that are overlain by lowe
post-earthquake dissipat
ter pressures. In this ca
water beneath the lowe
loosening, strength loss
films (Whitman 1985).
following equation:

$$\frac{S_r}{\sigma'_{vo}} = \exp\left(\frac{(N_1)_{60cs-Sr}}{16} + \left(\frac{(N_1)_{60cs-Sr} - 16}{21.2}\right)^3 - 3.0\right) \le \tan\phi' \quad (81)$$

The potential role of void redistribution or other strength loss mechanisms in the case histories is not fully clear at this time. Physical and analytical models indicate that void redistribution is potentially most severe for loose sands and is likely to have played a role in many of the currently available case histories. This would suggest that the two design relationships should be somewhat different at the lower penetration resistances, but the current state of knowledge does not provide a basis for incorporating any difference at this time.

Similar relationships for a CPT-based evaluation of S_r/σ'_{vc} are shown in Figure 90, along with the same case histories that were used to develop the SPT-based relationship in Figure 89. For many of the case histories, it was necessary to convert available SPT data into CPT data via a combination of empirical correlations (e.g., Suzuki et al. 1998, Cubrinovski and Ishihara 1999, Salgado et al. 1997b),

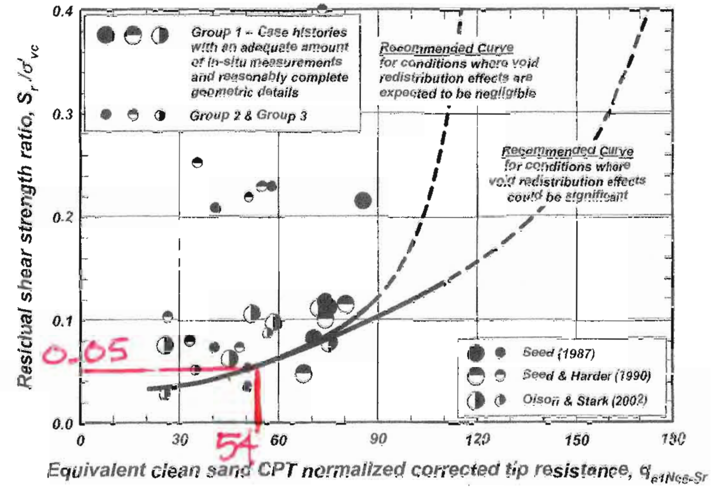


Figure 90. Correlation between the normalized residual shear strength ratio for liquefied soils and overburden-corrected CPT penetration resistance (σ'_{vc} < 400 kPa).

as described in Idriss and Boulanger (2007). CPT penetration resistances were then adjusted to equivalent clean-sand values by using the Δq_{c1N} values in Table 5, which were derived for consistency with the SPT corrections recommended by Seed (1987). The recommended relationships for S_r/σ'_{vc} can be calculated as

$$\frac{S_r}{\sigma'_{vo}} = \exp\left(\frac{q_{c1Ncs-Sr}}{24.5} - \left(\frac{q_{c1Ncs-Sr}}{61.7}\right)^2 + \left(\frac{q_{c1Ncs-Sr}}{106}\right)^3 - 4.42\right) \le \tan\phi' \quad (82)$$

Table 5 Approximate values of Δq_{c1N-Sr} for CPT correlation with residual strengths.

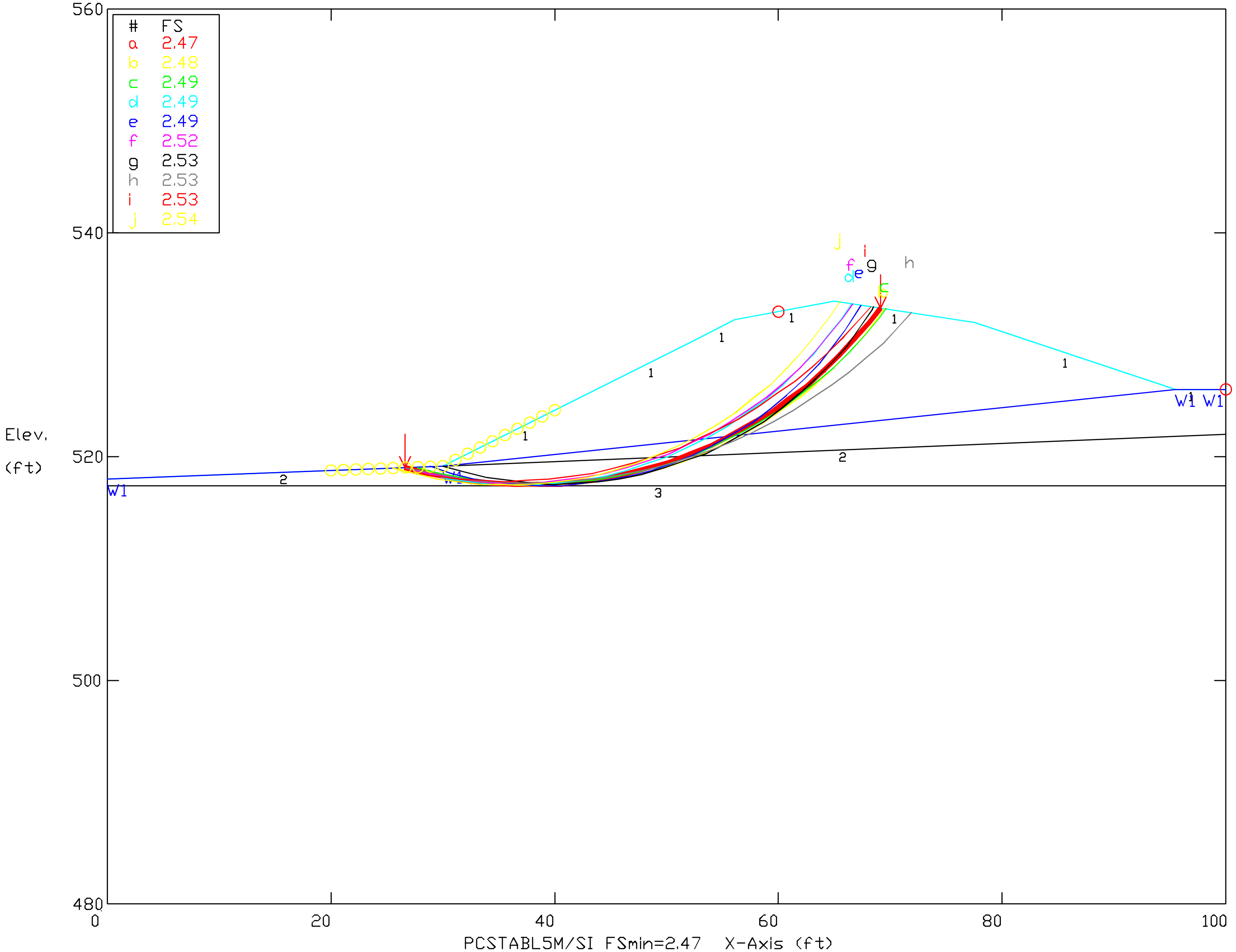
Fines content (% passing No. 200 sieve)	Δq_{c1N-Sr}
10	10
25	25
50	45
75	55

APPENDIX F – Slope Stability Analysis

Alliant Energy
Interstate Power and Light Company
Burlington Generating Station
Burlington, Iowa

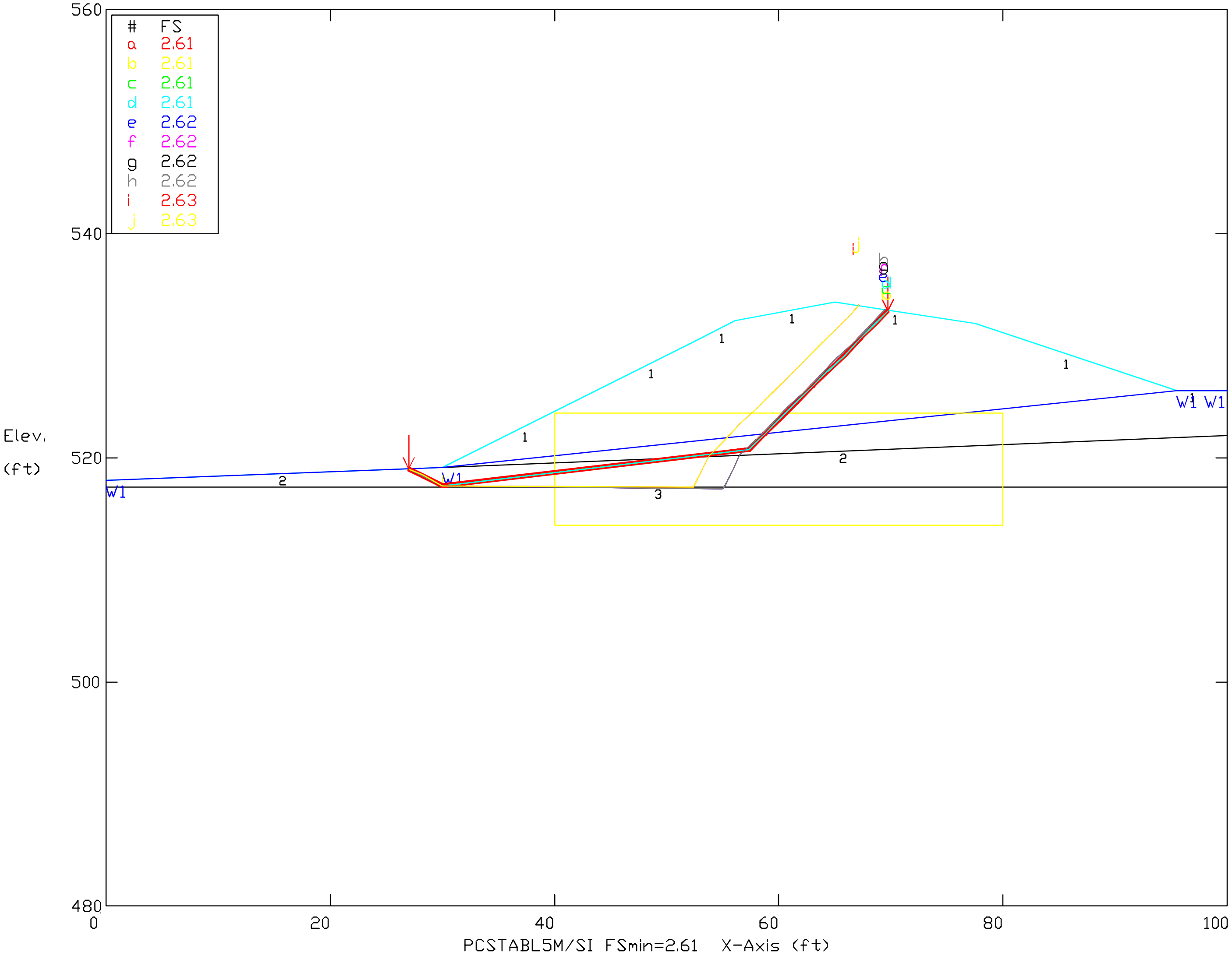
Safety Factor Assessment

BSG - Ash Seal Pond South Dike Static Case & Normal Water Level
Ten Most Critical. E:BSG50C.PLT 04-26-16 11:22am



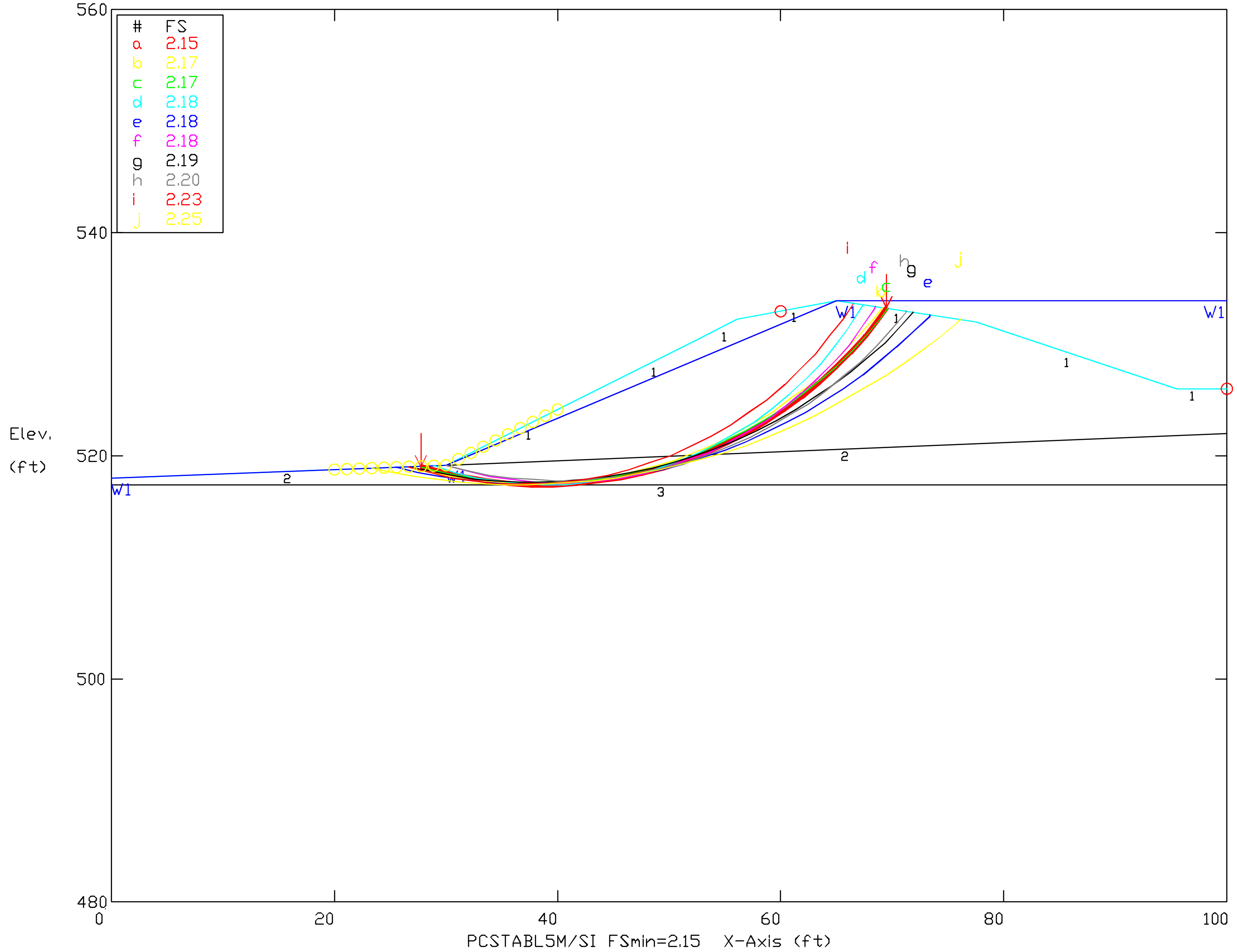
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Clay	120	120	700	0	0	0	W1
2	Sand	130	130	0	37	0	0	W1
3	Clay	125	125	900	0	0	0	W1

BSG - Ash Seal Pond South Dike Static Case & Normal Water Level
Ten Most Critical. E:BSG50B.PLT 04-26-16 10:53am



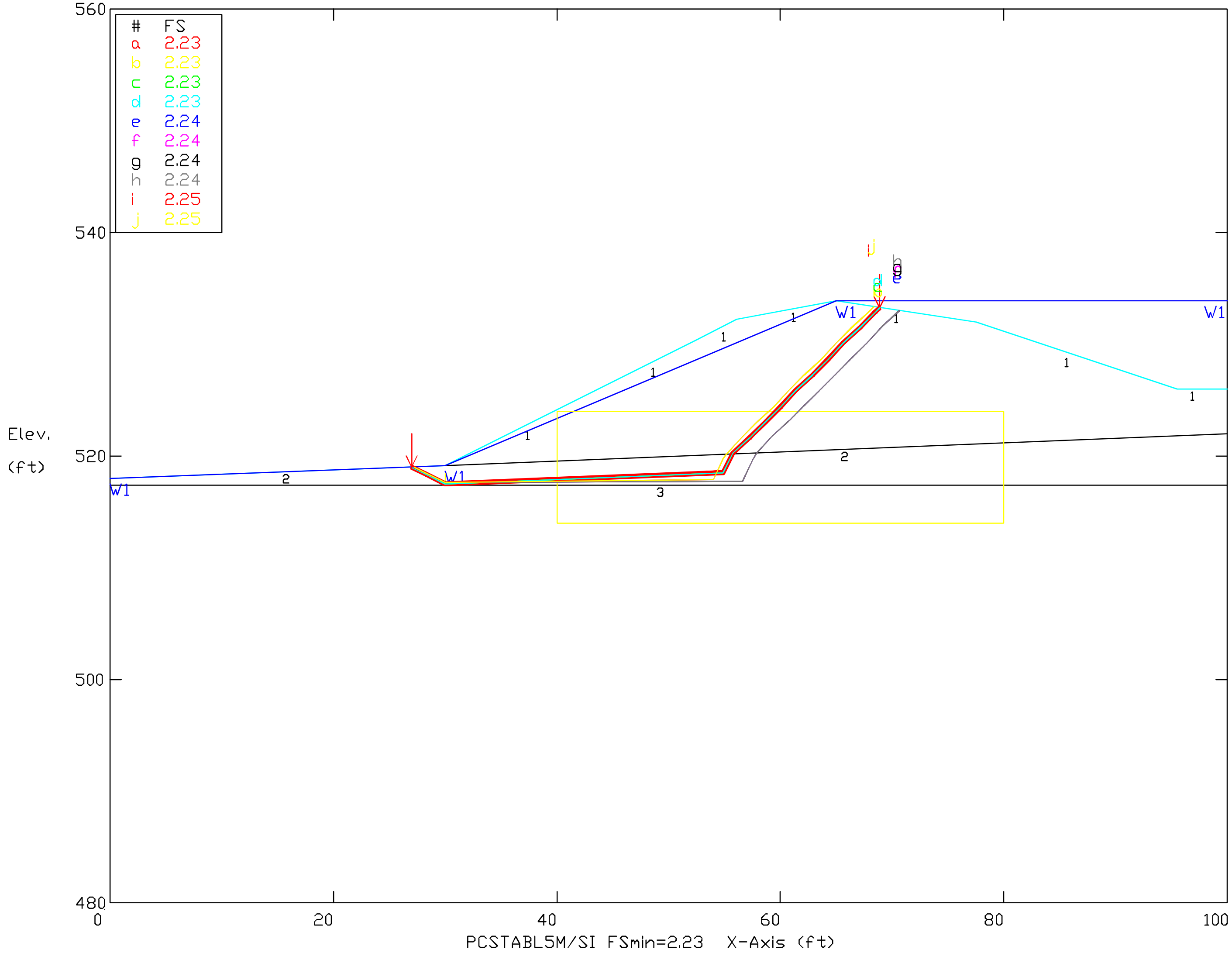
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Clay	120	120	700	0	0	0	W1
2	Sand	130	130	0	37	0	0	W1
3	Clay	125	125	900	0	0	0	W1

BSG - Ash Seal Pond South Dike Static Case with High Water Level
Ten Most Critical. E:BSG50CW.PLT 04-26-16 11:15am



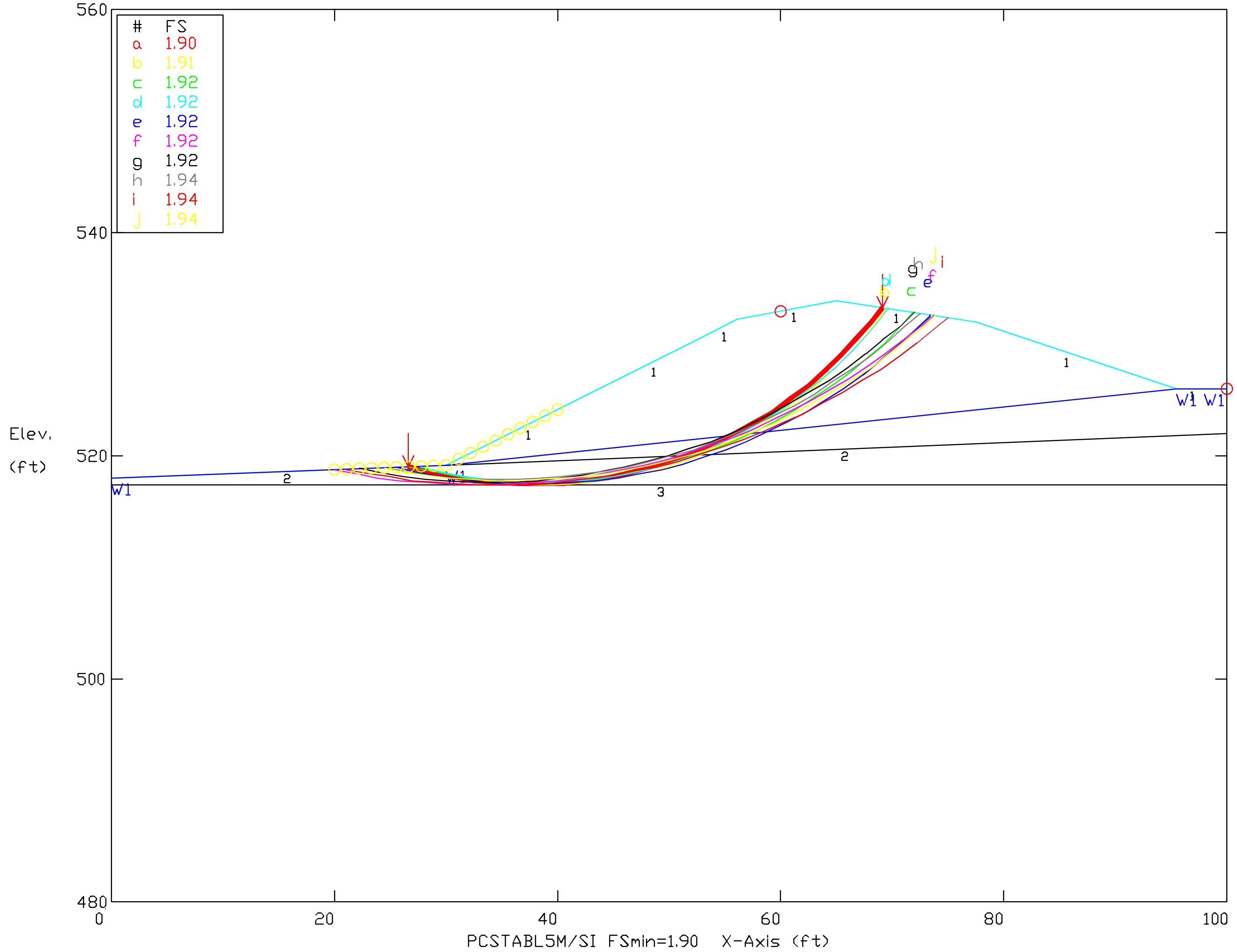
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Clay	120	120	700	0	0	0	W1
2	Sand	130	130	0	37	0	0	W1
3	Clay	125	125	900	0	0	0	W1

BSG - Ash Seal Pond South Dike Static Case with High Water Level
Ten Most Critical. E:BSG50BW.PLT 04-26-16 11:18am



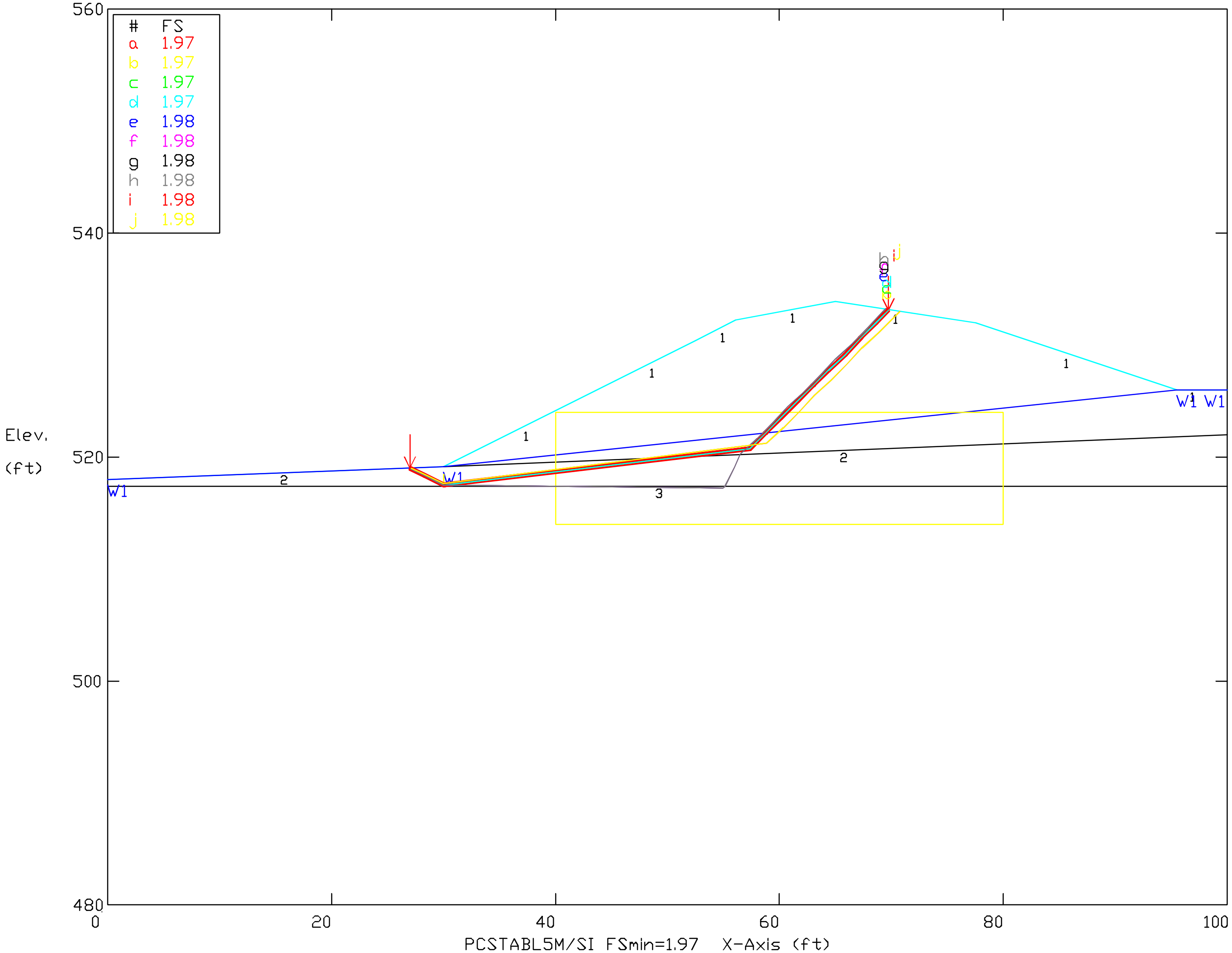
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Clay	120	120	700	0	0	0	W1
2	Sand	130	130	0	37	0	0	W1
3	Clay	125	125	900	0	0	0	W1

BSG - Ash Seal Pond South Dike EQ Case (0.105 & -0.070) & Normal Water
Ten Most Critical. E:BSG50CEQ.PLT 04-26-16 10:56am



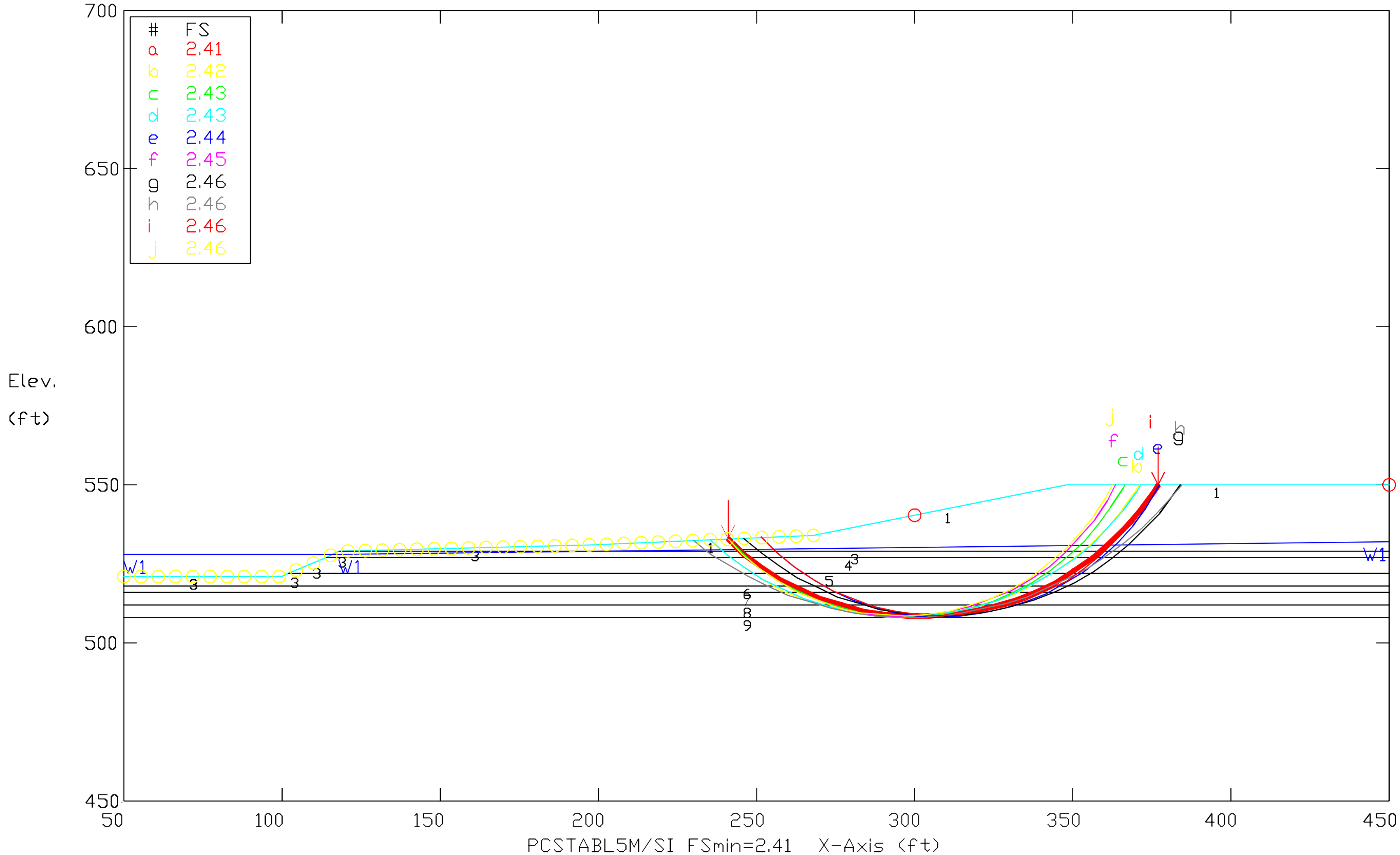
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Clay	120	120	700	0	0	0	W1
2 Sand	130	130	0	37	0	0	W1
3 Clay	125	125	900	0	0	0	W1

BSG - Ash Seal Pond South Dike EQ Case (0.105 & -0.070) & Normal Water
Ten Most Critical. E:BSG50BEQ.PLT 04-26-16 10:59am



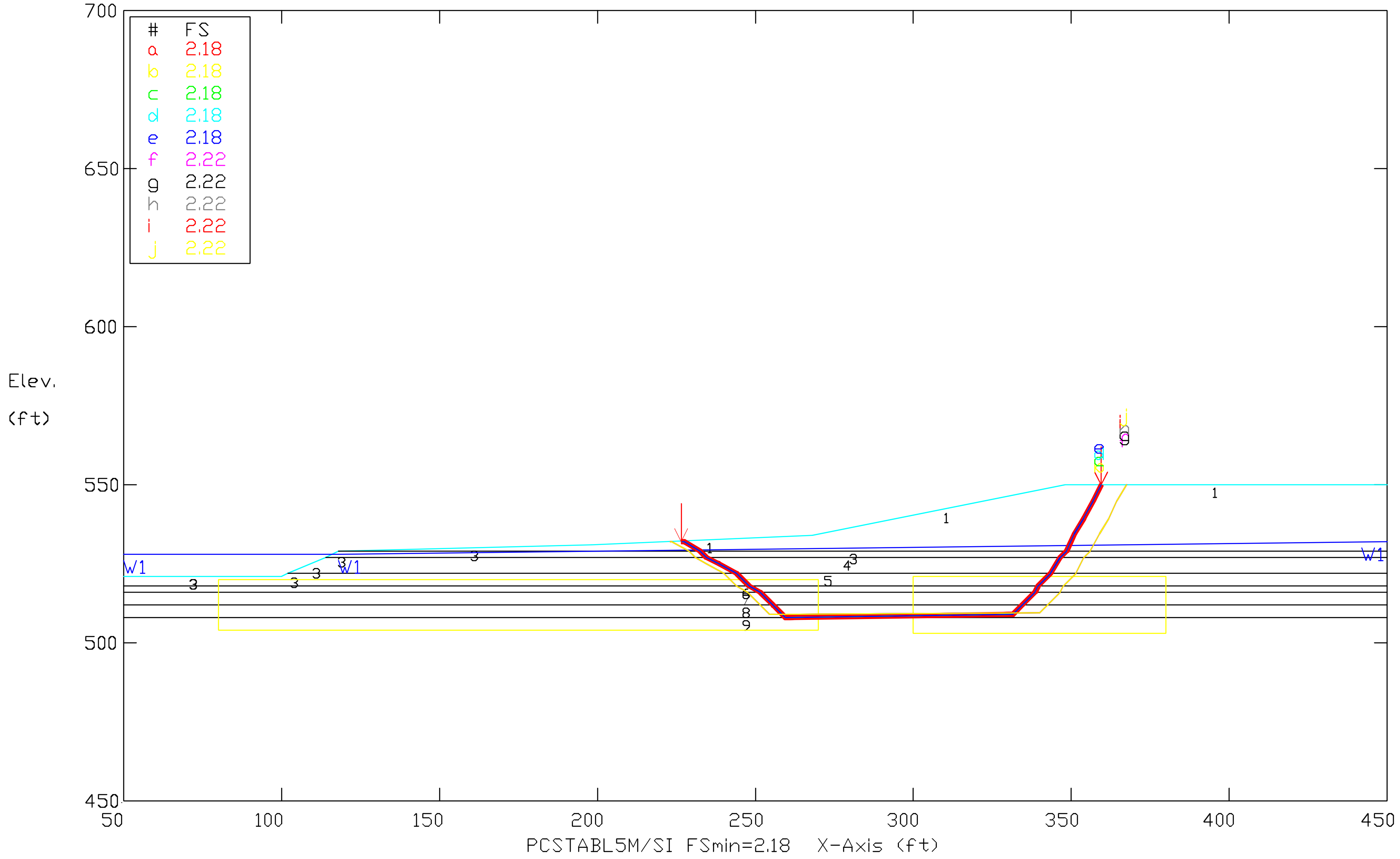
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Clay	120	120	700	0	0	0	W1
2	Sand	130	130	0	37	0	0	W1
3	Clay	125	125	900	0	0	0	W1

BSG - Economizer Pond North Eastern Sec. As Rebuilt, Static Case & Normal Pond
Ten Most Critical. E:BGS00C.PLT   04-24-16   3:04pm



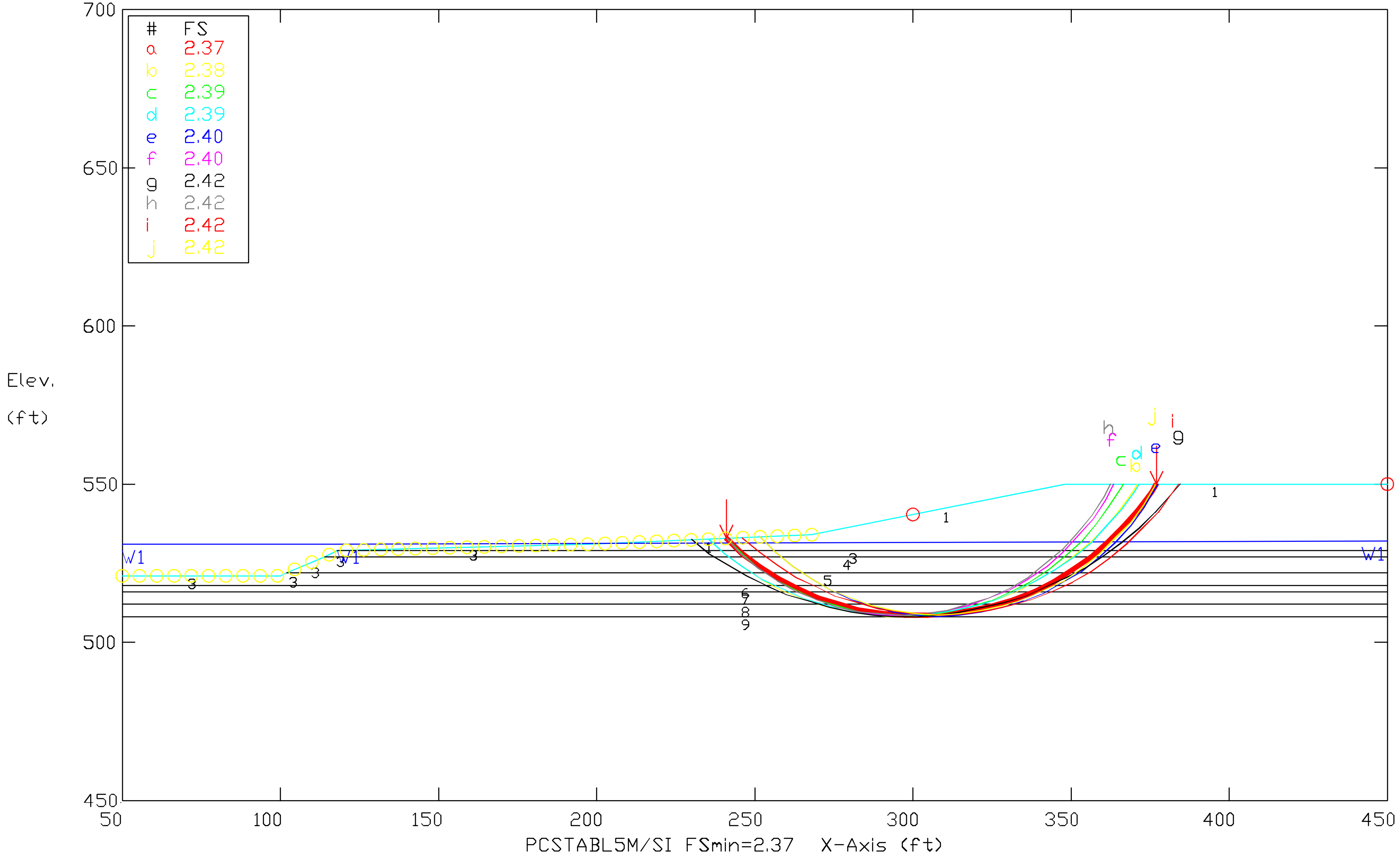
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	DIKE	125	125	0	34	0	0	W1
2	ASH	120	120	0	34	0	0	W1
3	CLAY	125	125	1000	0	0	0	W1
4	ASH	120	120	0	32	0	0	W1
5	CLAY	125	125	1000	0	0	0	W1
6	ASH	120	120	0	32	0	0	W1
7	CLAY	125	125	600	0	0	0	W1
8	CLAY	125	125	600	0	0	0	W1
9	SAND	125	125	0	30	0	0	W1

BSG - Economizer Pond North Eastern Sec. As Rebuilt, Static Case & Normal Pond
Ten Most Critical. E:BGS00B.PLT 04-24-16 2:56pm



Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	DIKE	125	125	0	34	0	0	W1
2	ASH	120	120	0	34	0	0	W1
3	CLAY	125	125	1000	0	0	0	W1
4	ASH	120	120	0	32	0	0	W1
5	CLAY	125	125	1000	0	0	0	W1
6	ASH	120	120	0	32	0	0	W1
7	CLAY	125	125	600	0	0	0	W1
8	CLAY	125	125	600	0	0	0	W1
9	SAND	125	125	0	30	0	0	W1

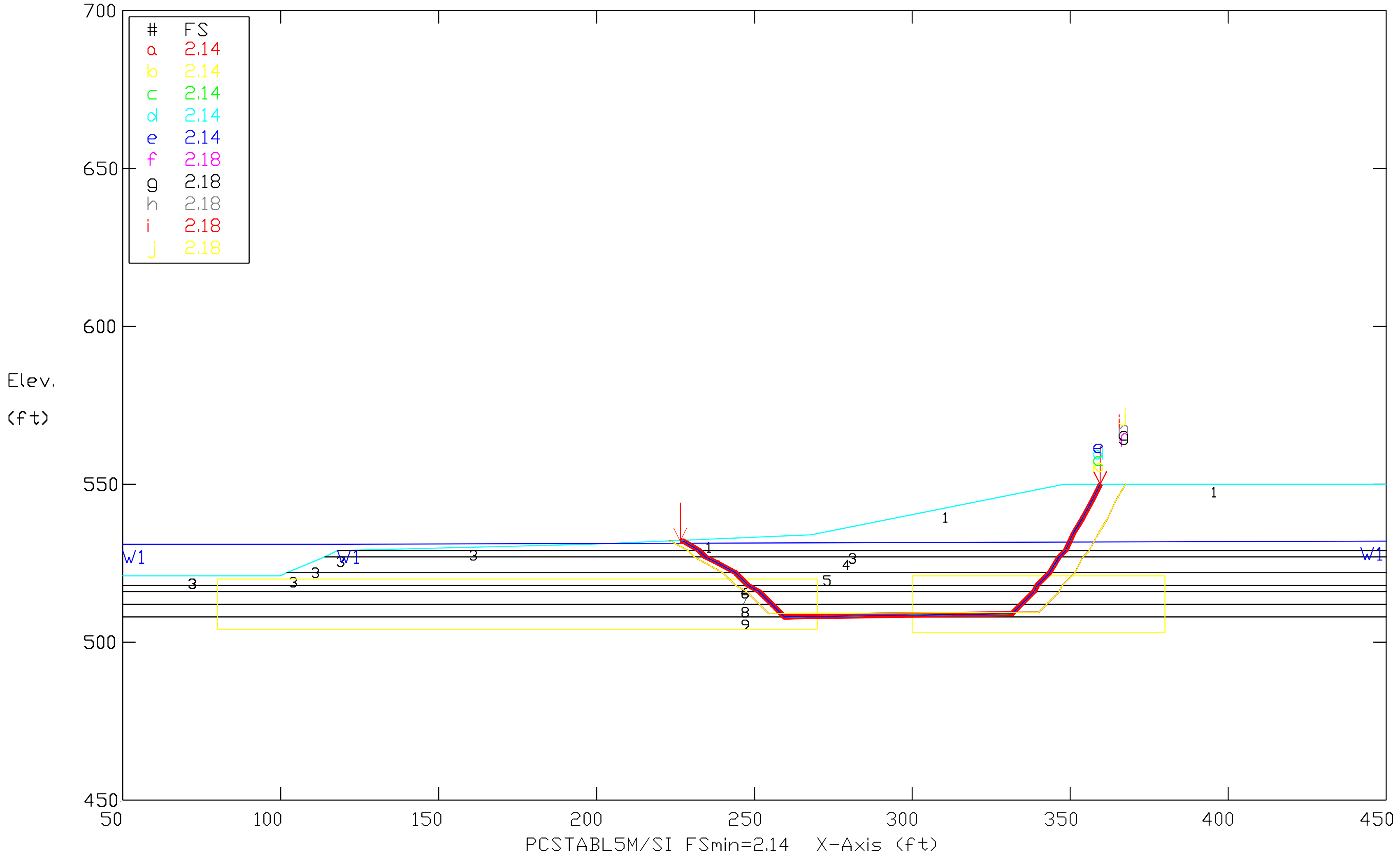
BSG - Economizer Pond North Eastern Sec. As Rebuilt, Static Case & Pond @ 531'
Ten Most Critical. E:BGS00CW.PLT 04-24-16 3:09pm



Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	DIKE	125	125	0	34	0	0	W1
2	ASH	120	120	0	34	0	0	W1
3	CLAY	125	125	1000	0	0	0	W1
4	ASH	120	120	0	32	0	0	W1
5	CLAY	125	125	1000	0	0	0	W1
6	ASH	120	120	0	32	0	0	W1
7	CLAY	125	125	600	0	0	0	W1
8	CLAY	125	125	600	0	0	0	W1
9	SAND	125	125	0	30	0	0	W1

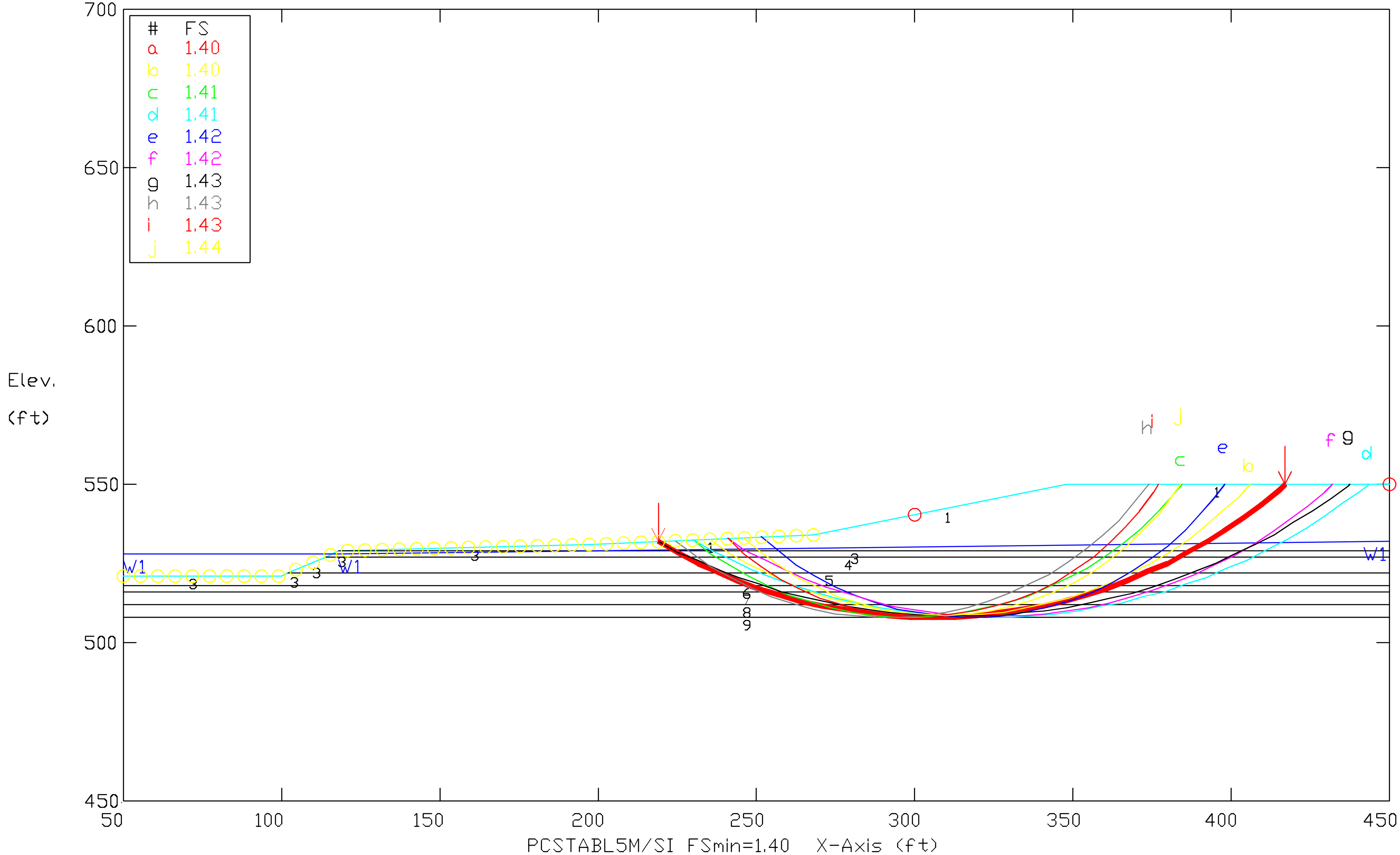
BSG - Economizer Pond North Eastern Sec. As Rebuilt, Static Case & Pond @ 531'

Ten Most Critical. E:BGS00BW.PLT 04-24-16 2:59pm



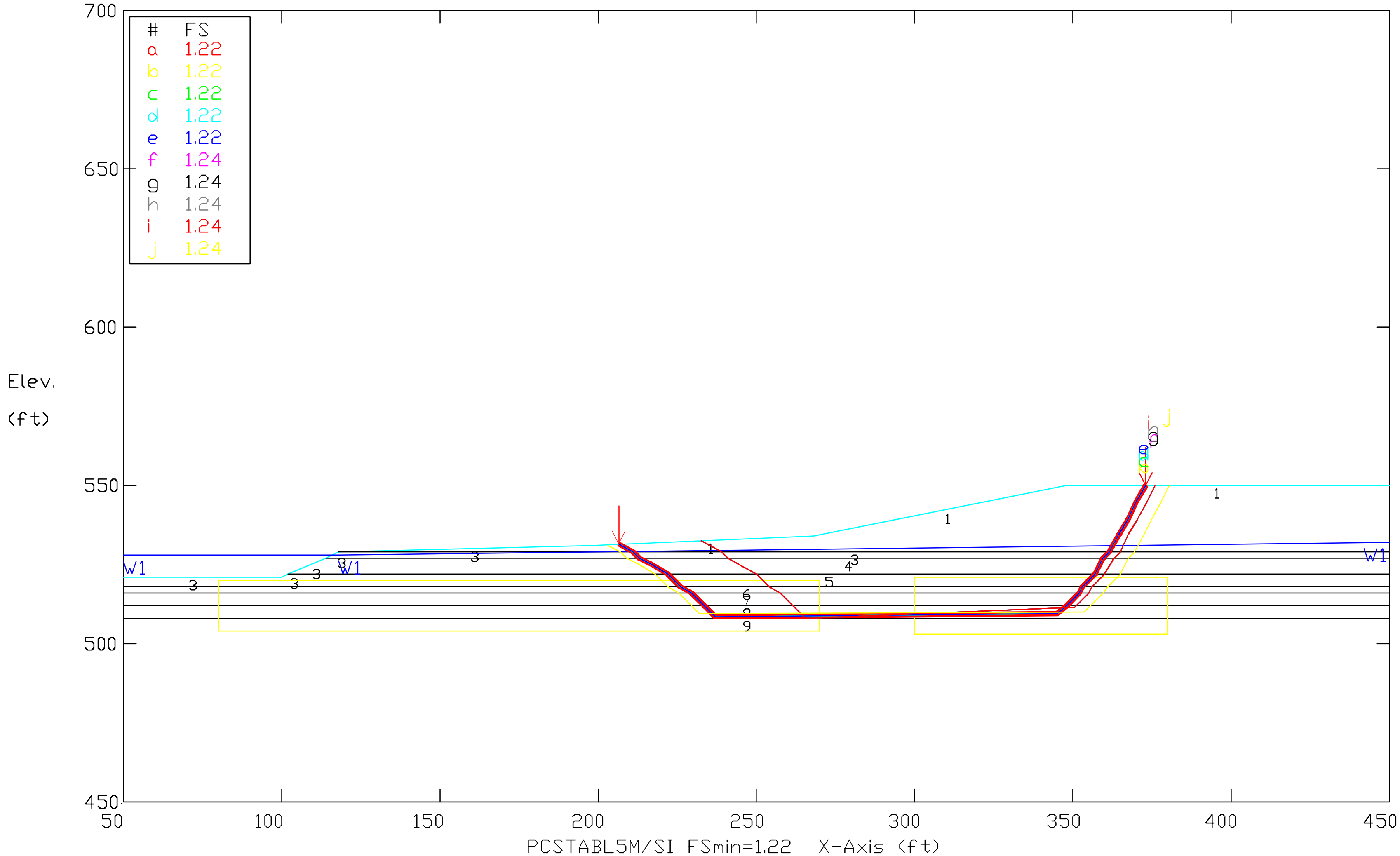
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	DIKE	125	125	0	34	0	0	W1
2	ASH	120	120	0	34	0	0	W1
3	CLAY	125	125	1000	0	0	0	W1
4	ASH	120	120	0	32	0	0	W1
5	CLAY	125	125	1000	0	0	0	W1
6	ASH	120	120	0	32	0	0	W1
7	CLAY	125	125	600	0	0	0	W1
8	CLAY	125	125	600	0	0	0	W1
9	SAND	125	125	0	30	0	0	W1

BSG - Economizer Pond North Eastern Sec. As Rebuilt, EQ Case & Normal Pond
Ten Most Critical. E:BGS00CEQ.PLT   04-24-16   3:11pm



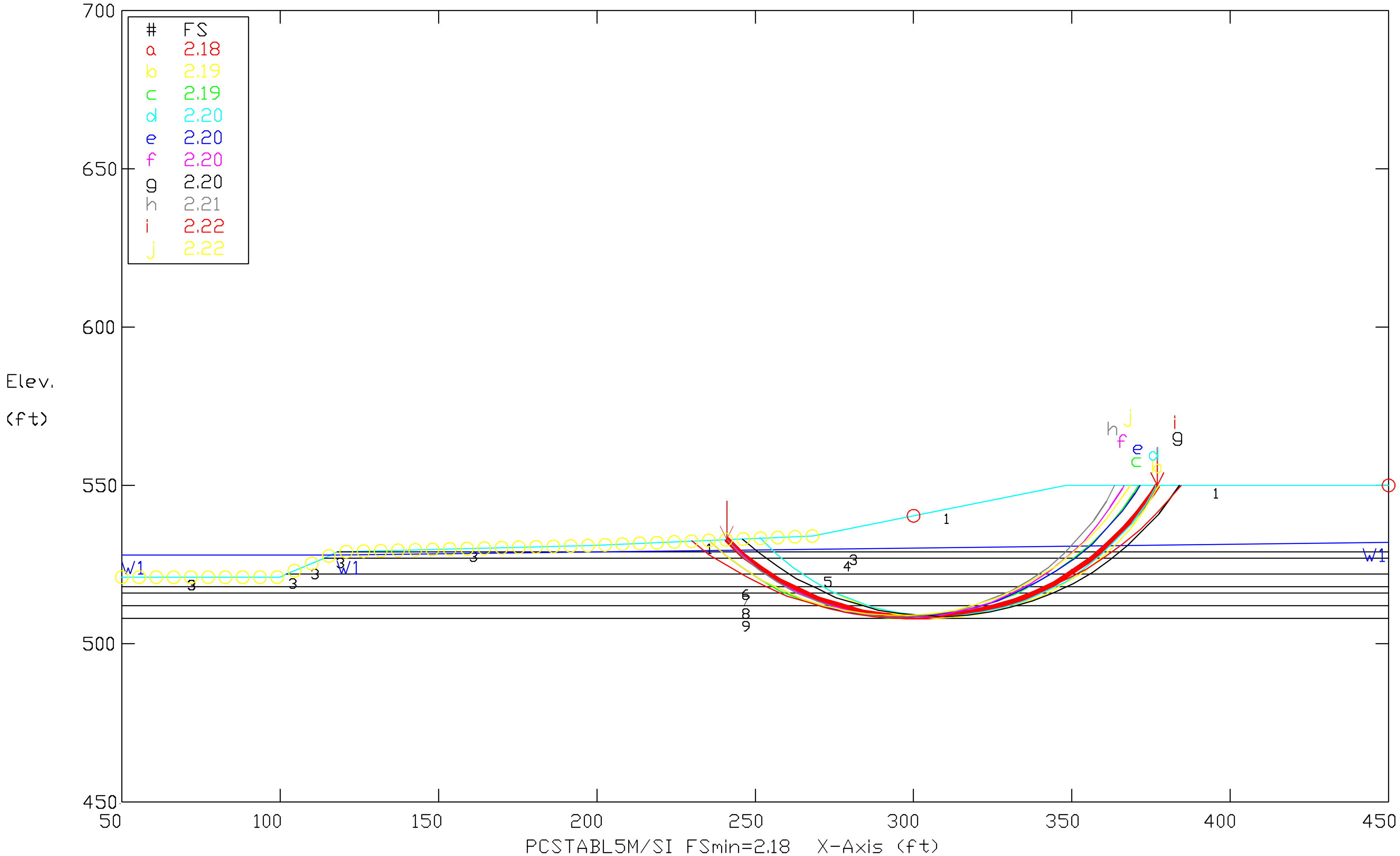
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	DIKE	125	125	0	34	0	0	W1
2	ASH	120	120	0	34	0	0	W1
3	CLAY	125	125	1000	0	0	0	W1
4	ASH	120	120	0	32	0	0	W1
5	CLAY	125	125	1000	0	0	0	W1
6	ASH	120	120	0	32	0	0	W1
7	CLAY	125	125	600	0	0	0	W1
8	CLAY	125	125	600	0	0	0	W1
9	SAND	125	125	0	30	0	0	W1

BSG - Economizer Pond North Eastern Sec. As Rebuilt, EQ Case & Normal Pond
Ten Most Critical. E:BGS00BEQ.PLT 04-24-16 3:02pm



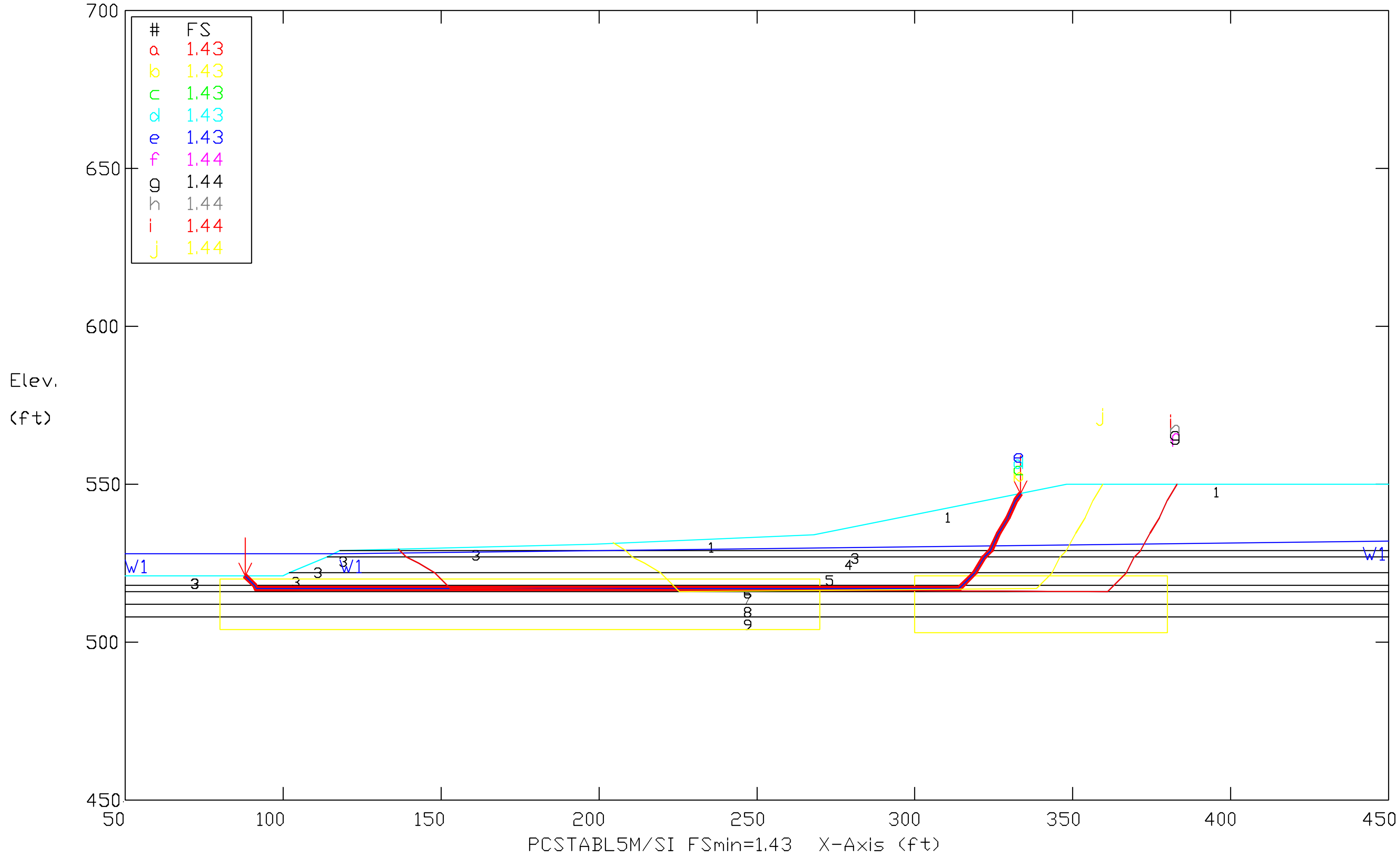
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	DIKE	125	125	0	34	0	0	W1
2	ASH	120	120	0	34	0	0	W1
3	CLAY	125	125	1000	0	0	0	W1
4	ASH	120	120	0	32	0	0	W1
5	CLAY	125	125	1000	0	0	0	W1
6	ASH	120	120	0	32	0	0	W1
7	CLAY	125	125	600	0	0	0	W1
8	CLAY	125	125	600	0	0	0	W1
9	SAND	125	125	0	30	0	0	W1

BSG - Economizer Pond North Eastern Sec.As Rebuilt, Liquified Case & Normal Pond
Ten Most Critical. E:BGS00CL.PLT 04-24-16 7:19pm



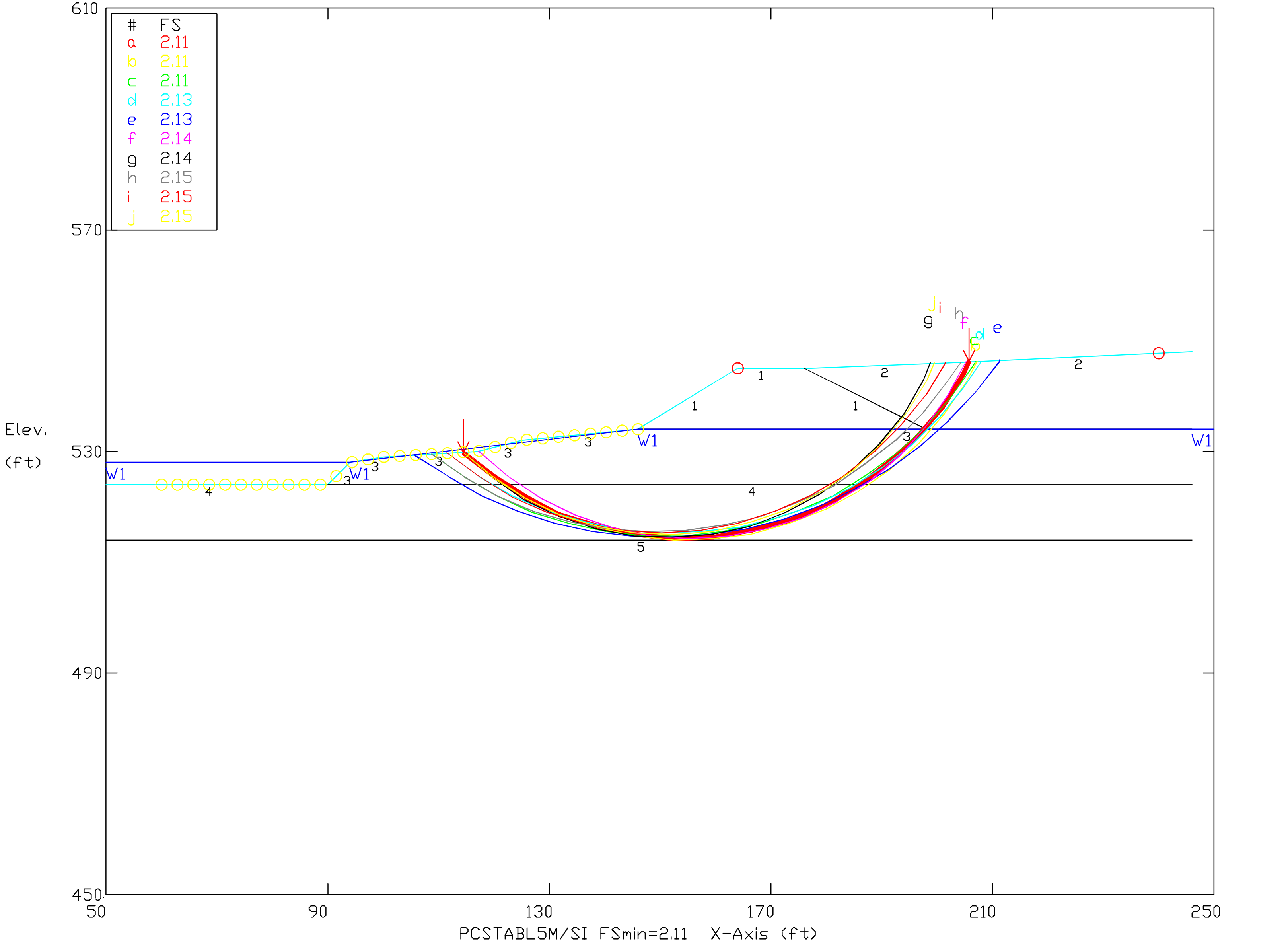
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 DIKE	125	125	0	34	0	0	W1
2 ASH	120	120	0	34	0	0	W1
3 CLAY	125	125	1000	0	0	0	W1
4 ASH	120	120	0	32	0	0	W1
5 CLAY	125	125	1000	0	0	0	W1
6 ASH	120	120	100	0	0	0	W1
7 CLAY	125	125	600	0	0	0	W1
8 CLAY	125	125	600	0	0	0	W1
9 SAND	125	125	0	30	0	0	W1

BSG - Economizer Pond North Eastern Sec.As Rebuilt, Liquified Case & Normal Pond
Ten Most Critical. E:BGS00BL.PLT 04-24-16 7:21pm



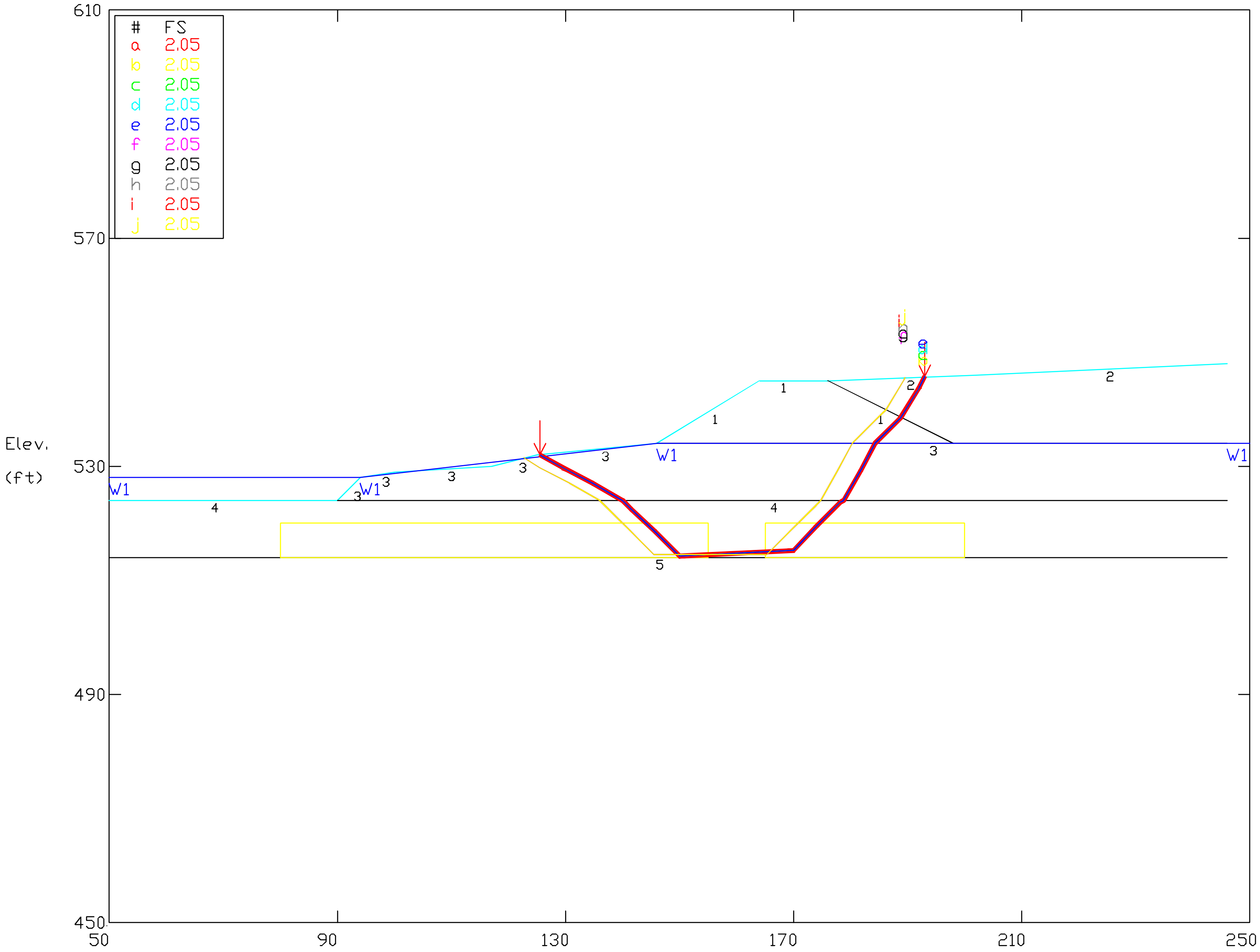
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 DIKE	125	125	0	34	0	0	W1
2 ASH	120	120	0	34	0	0	W1
3 CLAY	125	125	1000	0	0	0	W1
4 ASH	120	120	0	32	0	0	W1
5 CLAY	125	125	1000	0	0	0	W1
6 ASH	120	120	100	0	0	0	W1
7 CLAY	125	125	600	[illegible]	0	0	W1
8 CLAY	125	125	600	0	0	0	W1
9 SAND	125	125	0	30	0	0	W1

BSG - Economizer Pond Western Section As Rebiult, Static Case & Normal Pond
Ten Most Critical. E:BGS10C.PLT 04-24-16 3:40pm



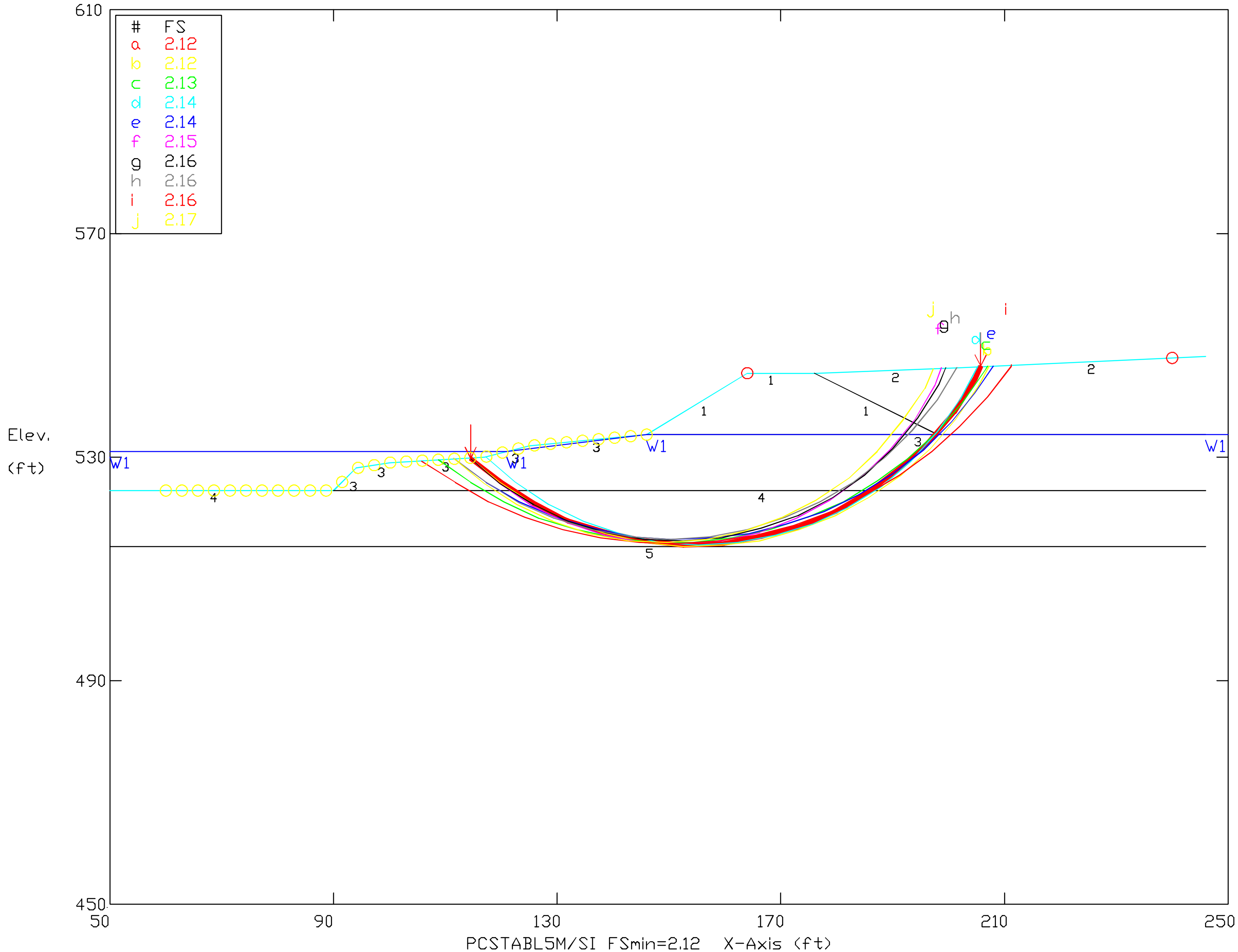
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Dike	125	125	1200	0	0	0	W1
2	Ash	120	120	0	28	0	0	W1
3	Ash Fdn	125	125	0	32	0	0	W1
4	Clay	125	125	700	0	0	0	W1
5	Sand	125	125	0	30	0	0	W1

BSG - Economizer Pond Western Section As Rebiult, Static Case & Normal Pond
Ten Most Critical. E:BGS10B.PLT 04-24-16 3:55pm



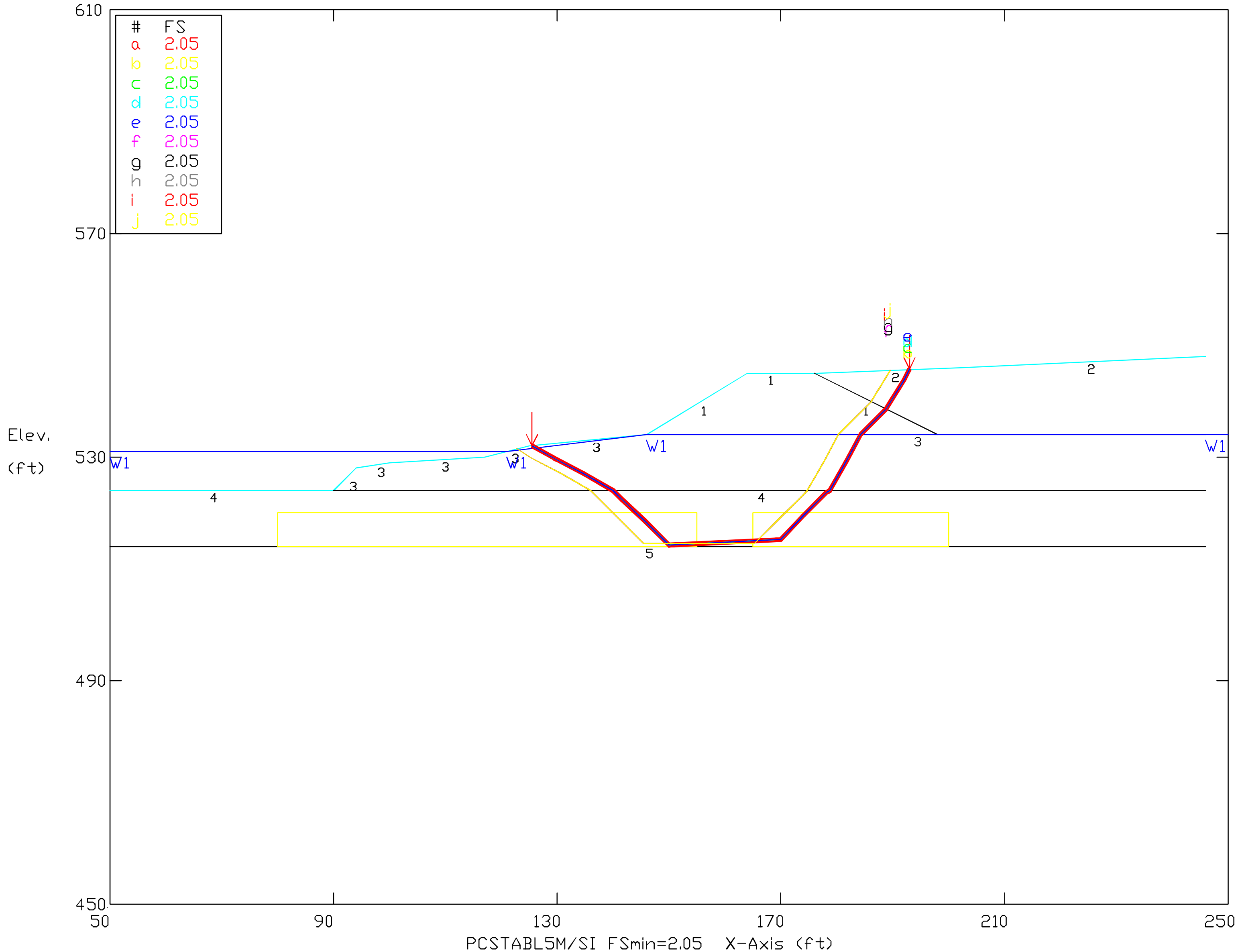
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Dike	125	125	1200	0	0	0	W1
2	Ash	120	120	0	28	0	0	W1
3	Ash Fill	125	125	0	32	0	0	W1
4	Clay	125	125	700	0	0	0	W1
5	Sand	125	125	0	30	0	0	W1

BSG - Economizer Pond Western Section As Rebiult, Static Case & Pond @ 531'
Ten Most Critical. E:BGS10CW.PLT 04-24-16 3:43pm



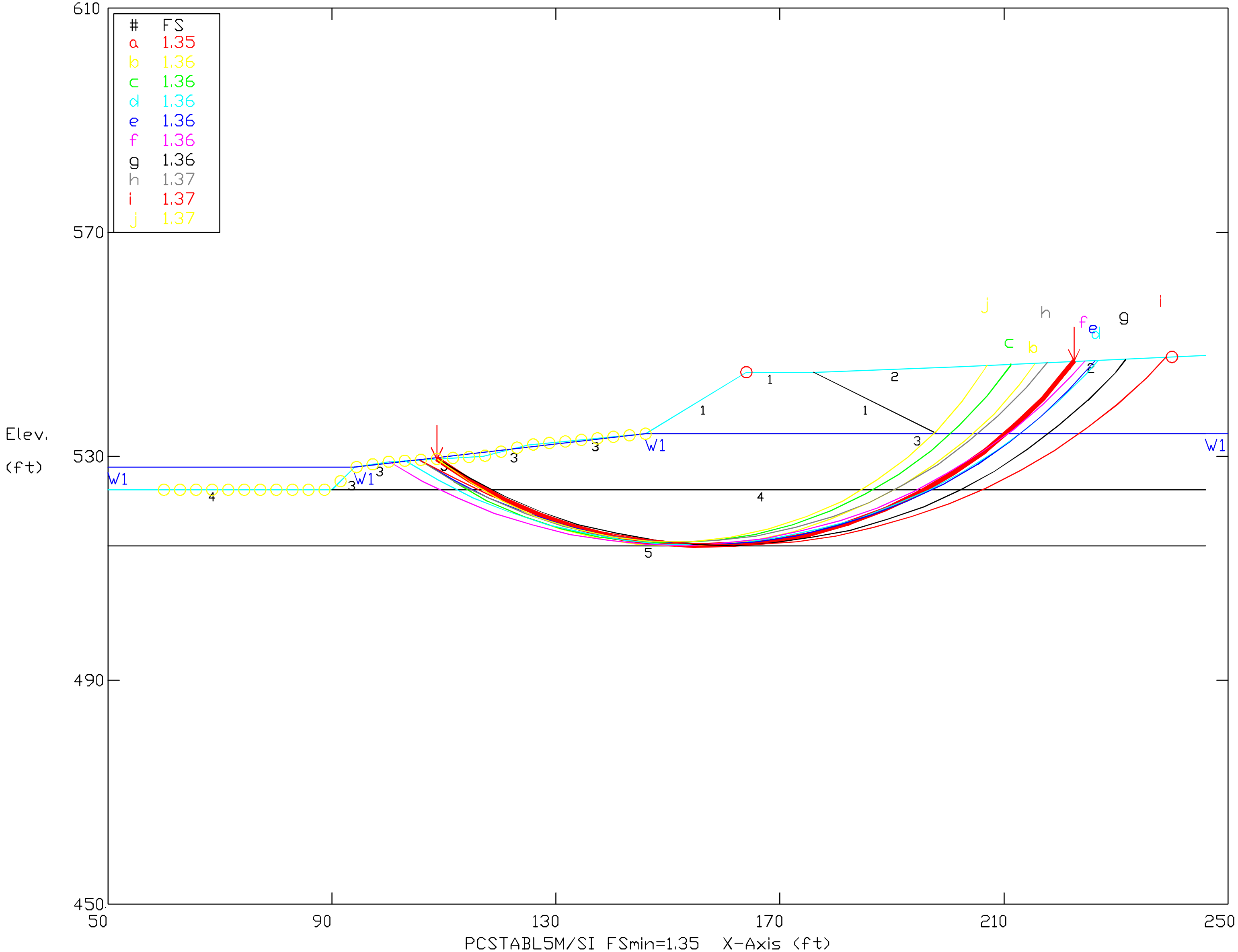
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Dike	125	125	1200	0	0	0	W1
2	Ash	120	120	0	28	0	0	W1
3	Ash + F[illegible]	125	125	0	32	0	0	W1
4	Clay	125	125	700	0	0	0	W1
5	Sand	125	125	0	30	0	0	W1

BSG - Economizer Pond Western Section As Rebiult, Static Case & Pond @ 531'
Ten Most Critical. E:BGS10BW.PLT 04-24-16 3:49pm



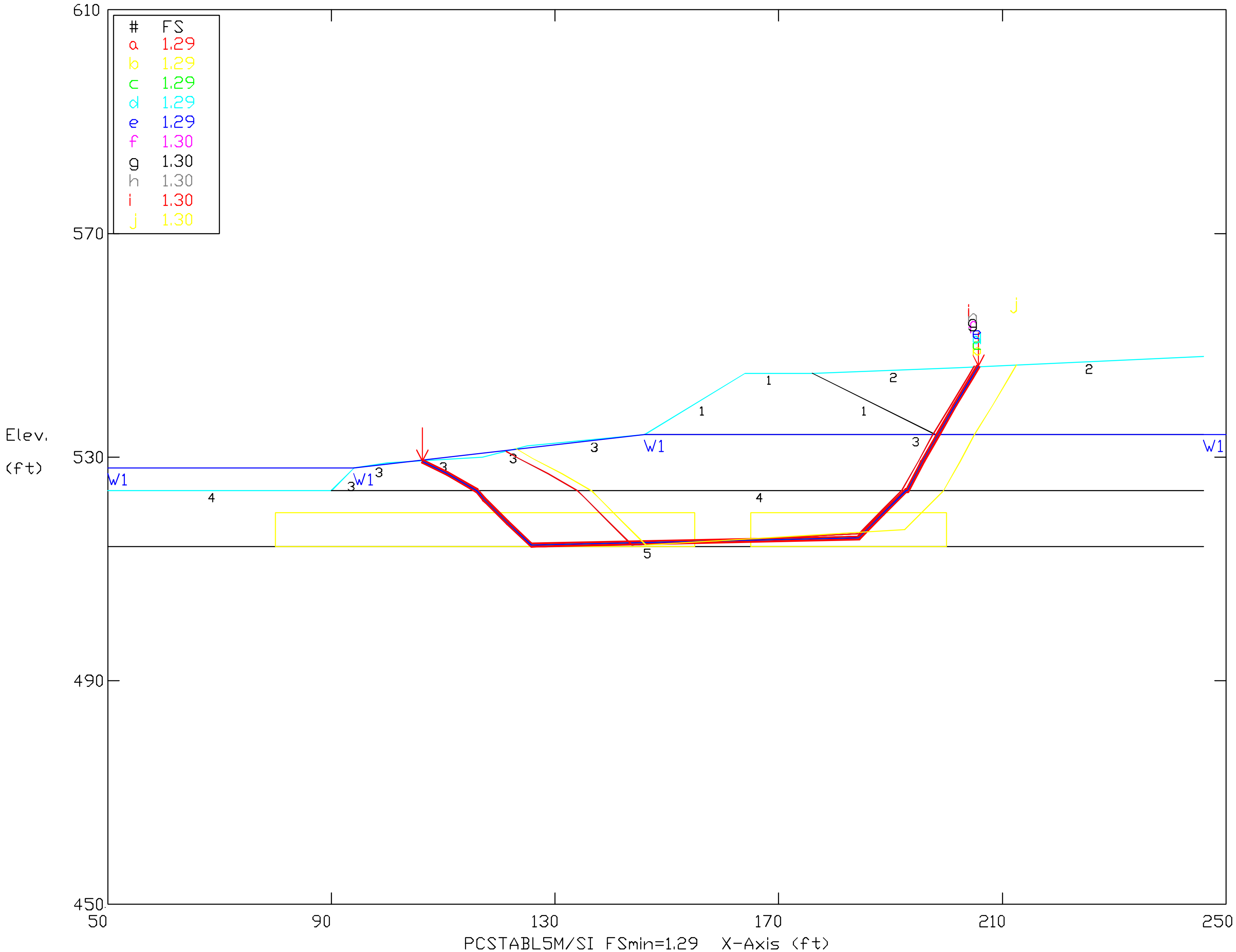
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Dike	125	125	1200	0	0	0	W1
2	Ash	120	120	0	28	0	0	W1
3	Ash - Fill	125	125	0	32	0	0	W1
4	Clay	125	125	700	0	0	0	W1
5	Sand	125	125	0	30	0	0	W1

BSG - Economizer Pond Western Section As Rebiult, EQ Case & Normal Pond
Ten Most Critical. E:BGS10CEQ.PLT 04-24-16 4:02pm



Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Dike	125	125	1200	0	0	0	W1
2	Ash	120	120	0	28	0	0	W1
3	Ash Fill	125	125	0	32	0	0	W1
4	Clay	125	125	700	0	0	0	W1
5	Sand	125	125	0	30	0	0	W1

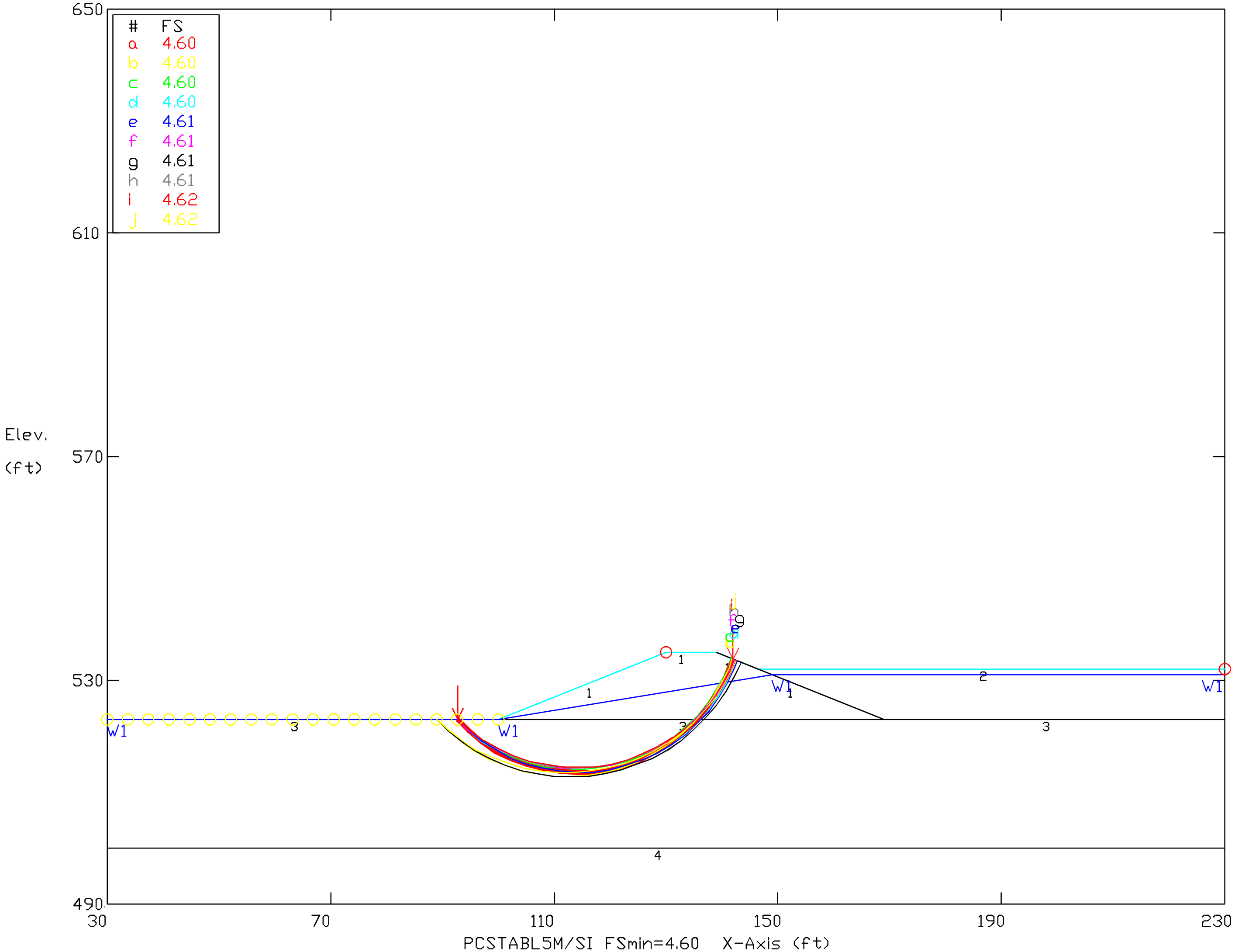
BSG - Economizer Pond Western Section As Rebiult, EQ Case & Normal Pond
Ten Most Critical. E:BGS10BEQ.PLT 04-24-16 3:58pm



Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Dike	125	125	1200	0	0	0	W1
2	Ash	120	120	0	28	0	0	W1
3	Ash F[illegible]	125	125	[illegible]	32	0	0	W1
4	Clay	125	125	700	0	0	0	W1
5	Sand	125	125	0	30	0	0	W1

BSG - Main Ash Pond South Dike Normal Water Level @ 531'

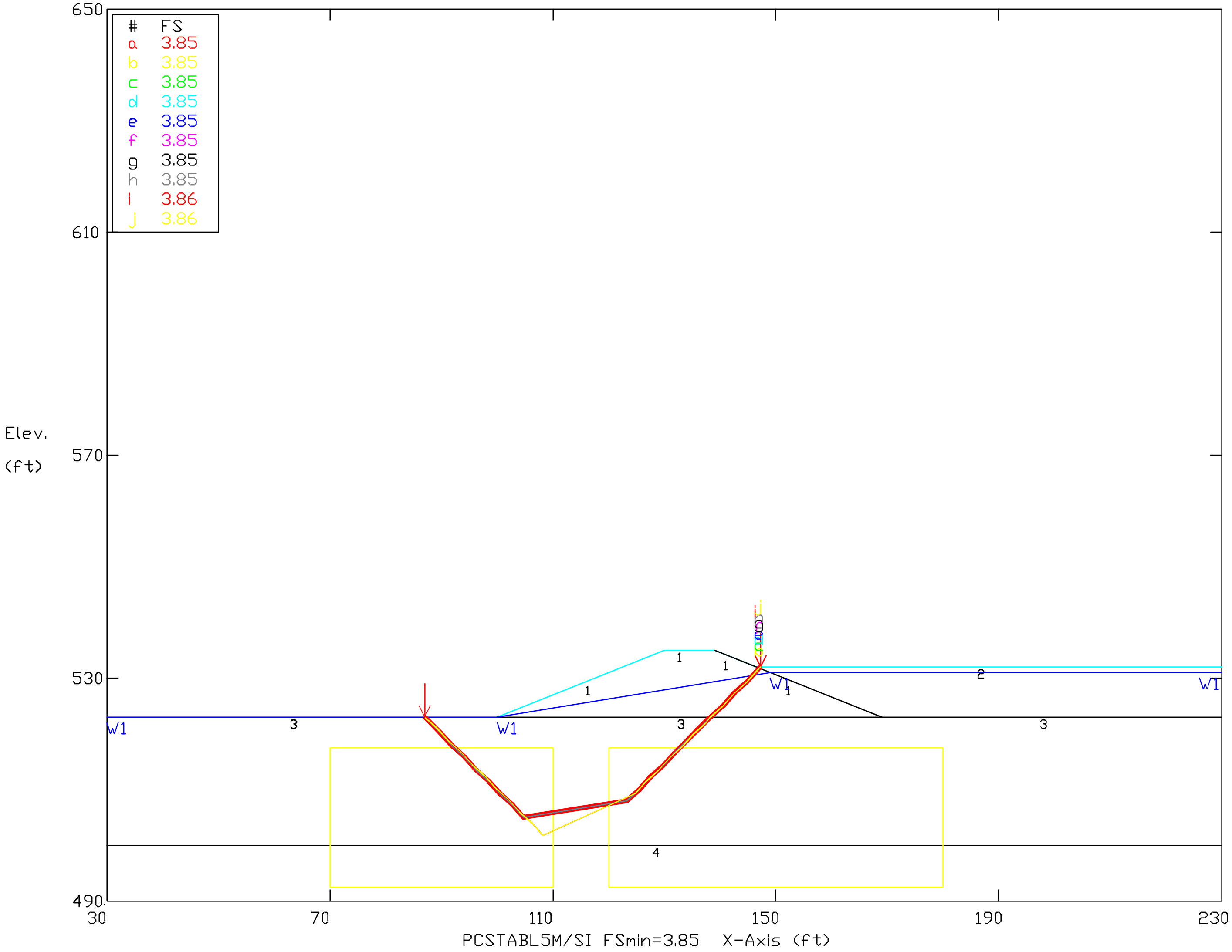
Ten Most Critical. E:BSG20C.PLT 04-26-16 8:57am



Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	125	125	700	0	0	0	W1
2 Ash	120	120	0	25	0	0	W1
3 Natural	120	120	1200	0	0	0	W1
4 Sand	130	130	0	37	0	0	W1

BSG - Main Ash Pond South Dike Normal Water Level @ 531'

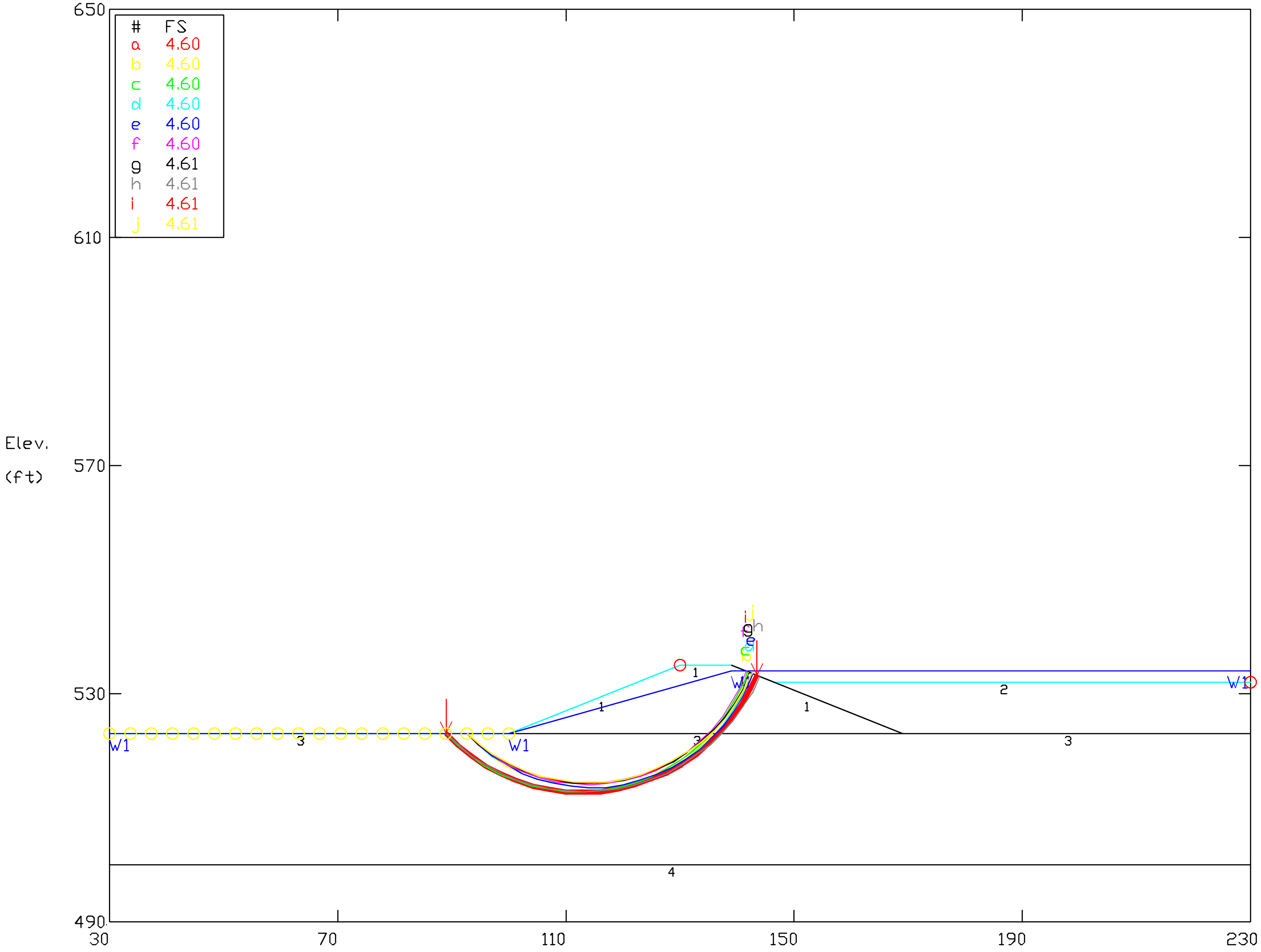
Ten Most Critical. E:BSG20B.PLT 04-26-16 8:58am



Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	125	125	700	0	0	0	W1
2 Ash	120	120	0	25	0	0	W1
3 Natural	120	120	1200	0	0	0	W1
4 Sand	130	130	0	37	0	0	W1

BSG - Main Ash Pond South Dike High Water Level @ 534'

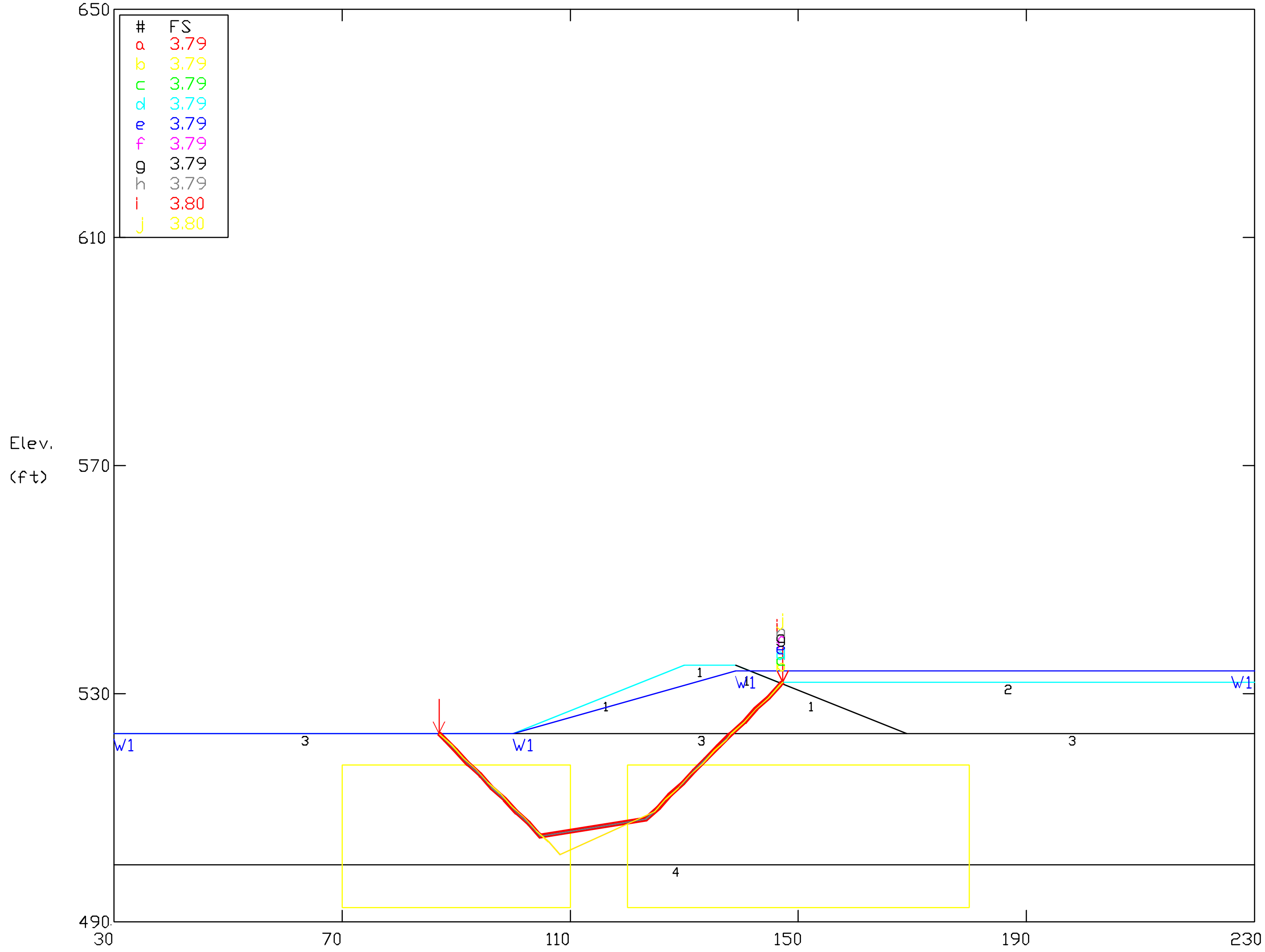
Ten Most Critical. E:BSG20CW.PLT 04-26-16 8:56am



Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	125	125	700	0	0	0	W1
2 Ash	120	120	0	25	0	0	W1
3 Natural	120	120	1200	0	0	0	W1
4 Sand	130	130	0	37	0	0	W1

BSG - Main Ash Pond South Dike High Water Level @ 534'

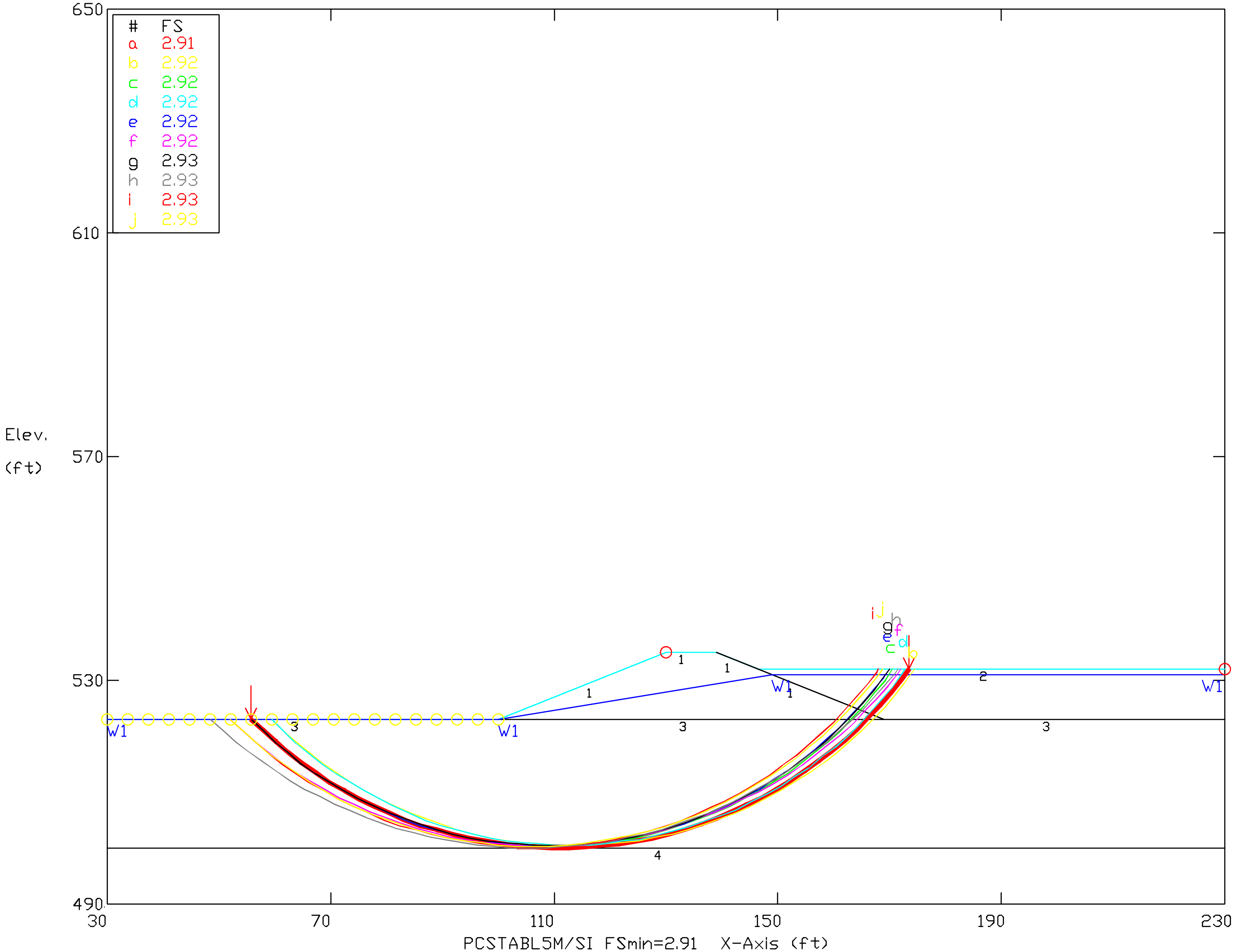
Ten Most Critical. E:BSG20BW.PLT 04-26-16 9:00am



PCSTABL5M/SI FSmin=3.79 X-Axis (ft)

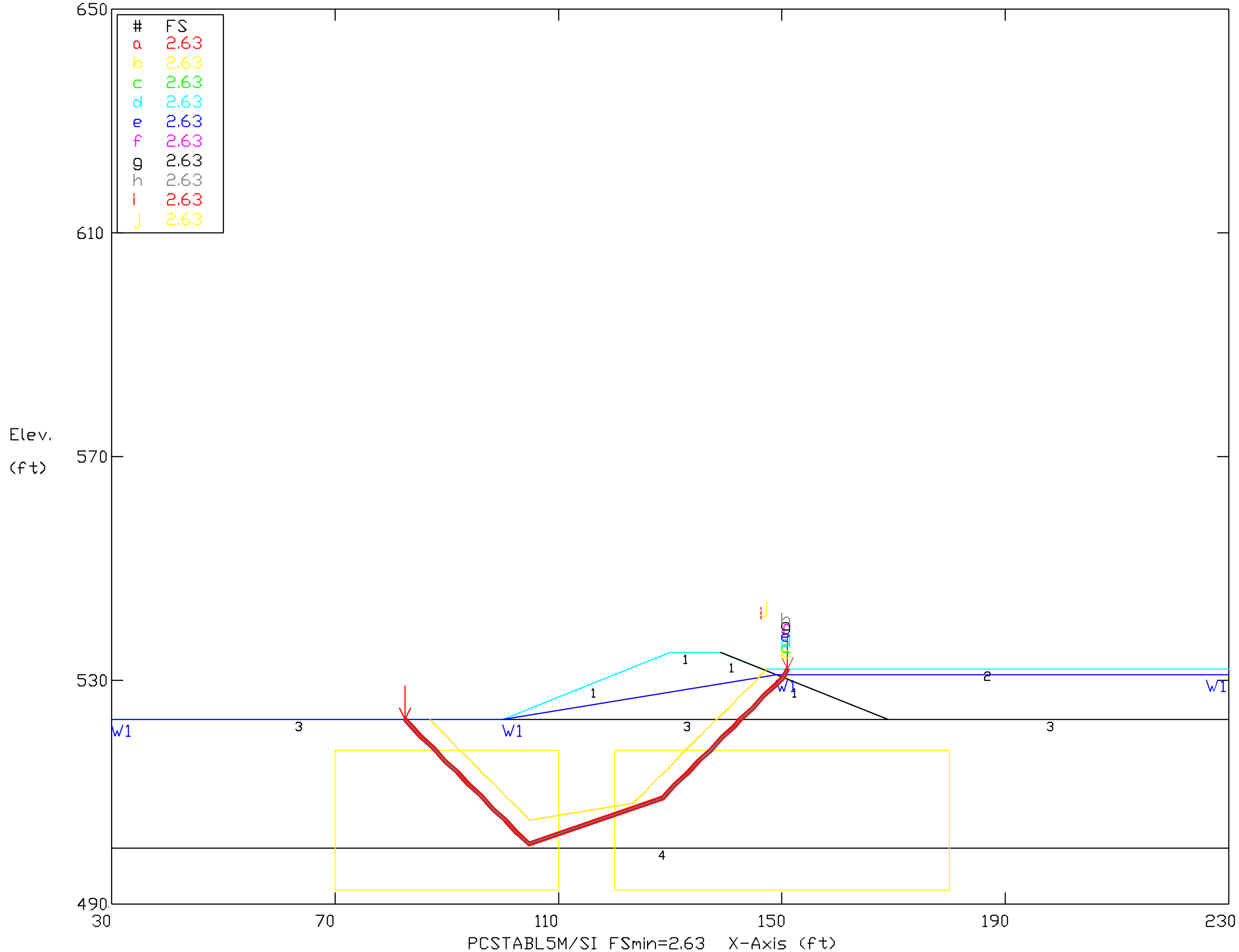
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Dike	125	125	700	0	0	0	W1
2	Ash	120	120	0	25	0	0	W1
3	Natural	120	120	1200	0	0	0	W1
4	Sand	130	130	0	37	0	0	W1

BSG - Main Ash Pond South Dike Normal Water Level & EQ (0.105 & -0.070)
Ten Most Critical. E:BSG20CEQ.PLT 04-26-16 9:08am



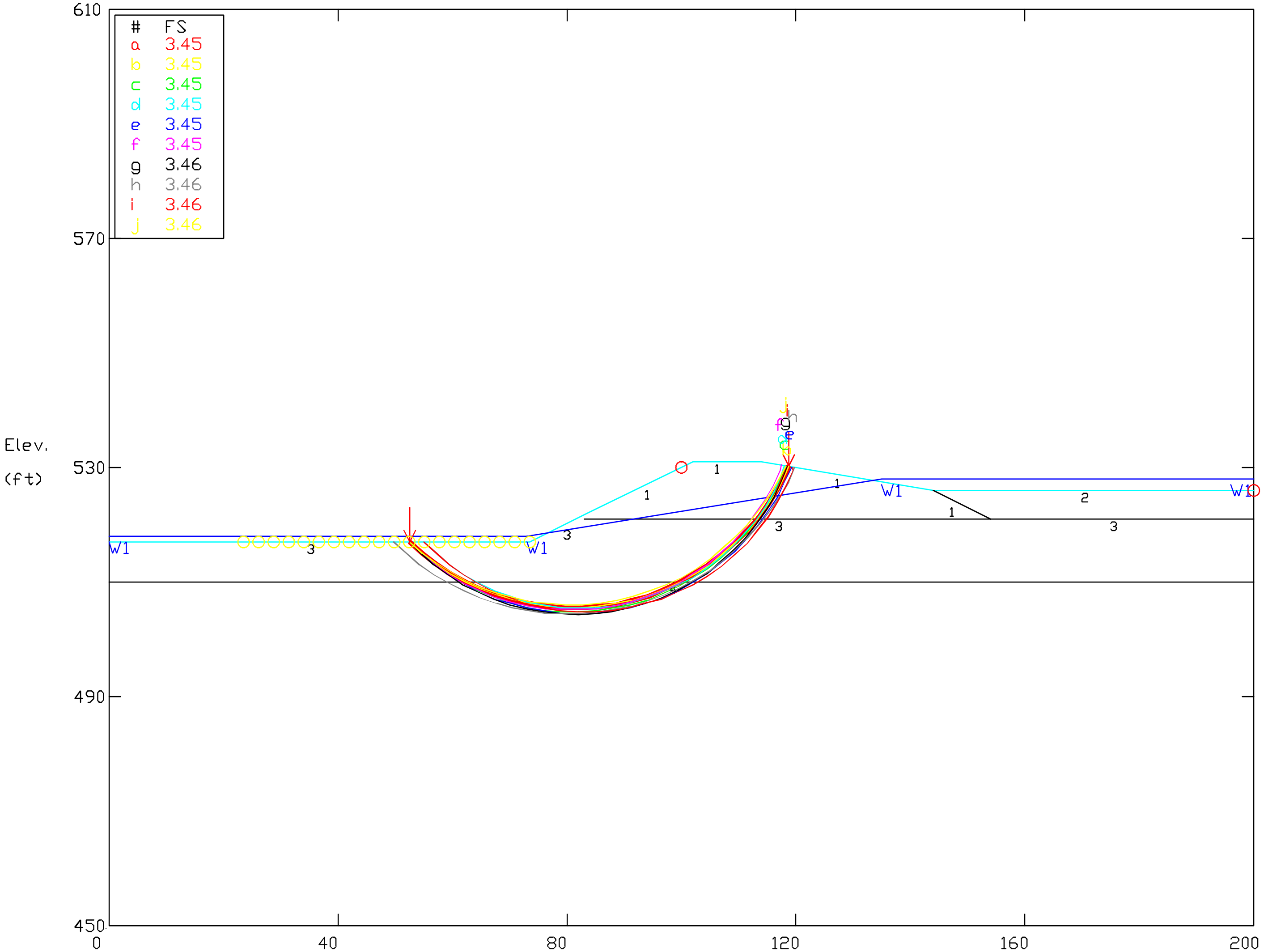
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Dike	125	125	700	0	0	0	W1
2	Ash	120	120	0	25	0	0	W1
3	Natural	120	120	1200	0	0	0	W1
4	Sand	130	130	0	37	0	0	W1

BSG - Main Ash Pond South Dike Normal Water Level & EQ (0.105 & -0.070)
Ten Most Critical. E:BSG20BEQ.PLT 04-26-16 9:03am



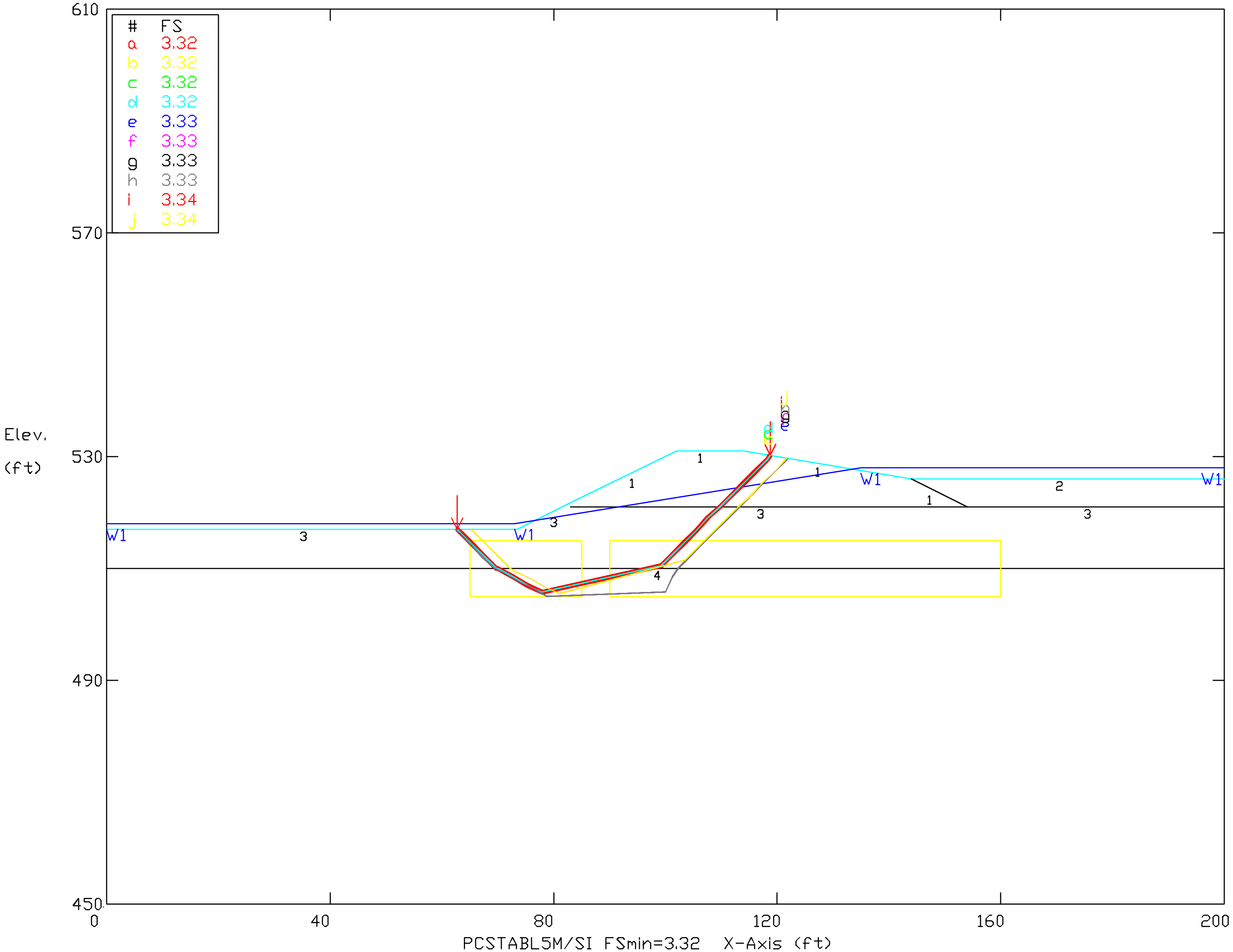
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	125	125	700	0	0	0	W1
2 Ash	120	120	0	25	0	0	W1
3 Natural	120	120	1200	0	0	0	W1
4 Sand	130	130	0	37	0	0	W1

BSG - Upper to Lower Ash Pond Dike Static Case & Normal Upper Pond (@ 528')
Ten Most Critical. E:BSG40C.PLT 04-25-16 4:45pm



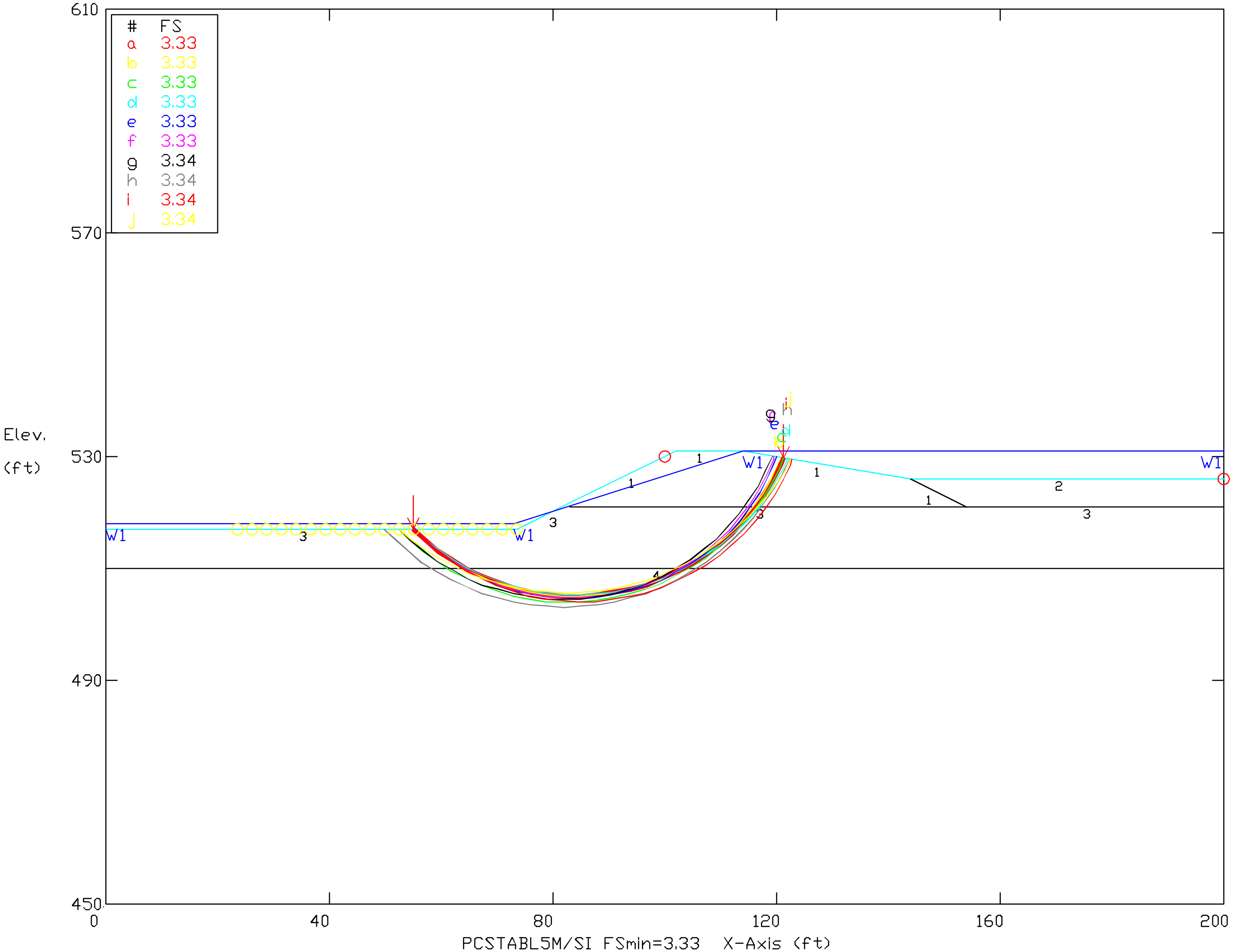
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	130	130	1950	0	0	0	W1
2 Ash	120	120	0	25	0	0	W1
3 Clay	125	125	900	0	0	0	W1
4 Sand	125	125	0	35	0	0	W1

BSG - Upper to Lower Ash Pond Dike Static Case & Normal Upper Pond (@ 528')
Ten Most Critical. E:BSG40B.PLT 04-25-16 4:53pm



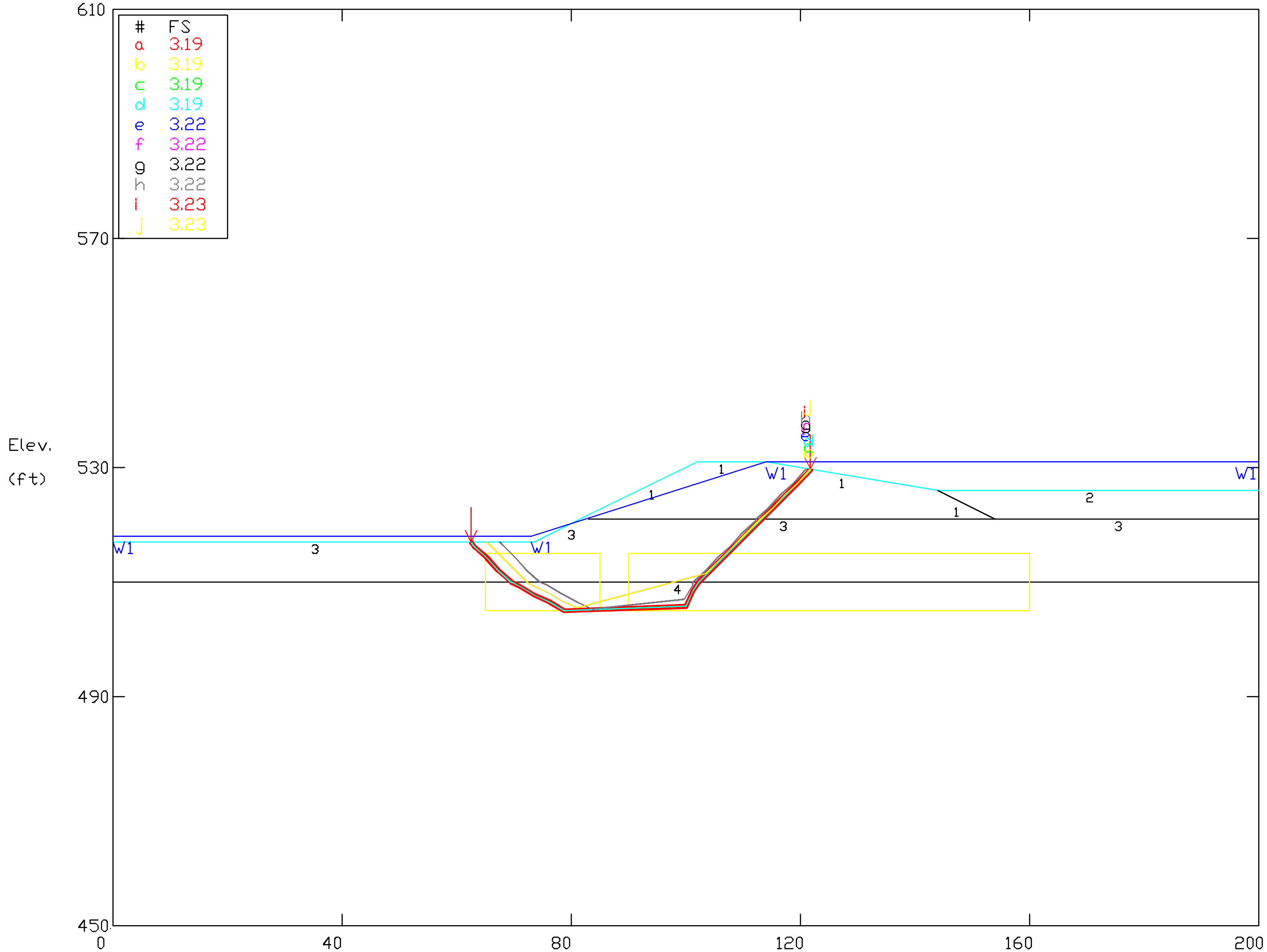
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	130	130	1950	0	0	0	W1
2 Ash	120	120	0	25	0	0	W1
3 Clay	125	125	900	0	0	0	W1
4 Sand	125	125	0	35	0	0	W1

BSG - Upper to Lower Ash Pond Dike Static Case & Max. Upper Pond (@ 531')
Ten Most Critical. E:BSG40CW.PLT 04-25-16 5:01pm



Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	130	130	1950	0	0	0	W1
2 Ash	120	120	0	25	0	0	W1
3 Clay	125	125	900	0	0	0	W1
4 Sand	125	125	0	35	0	0	W1

BSG - Upper to Lower Ash Pond Dike Static Case & Max. Upper Pond (@ 531')
Ten Most Critical. E:BSG40BW.PLT 04-25-16 5:29pm

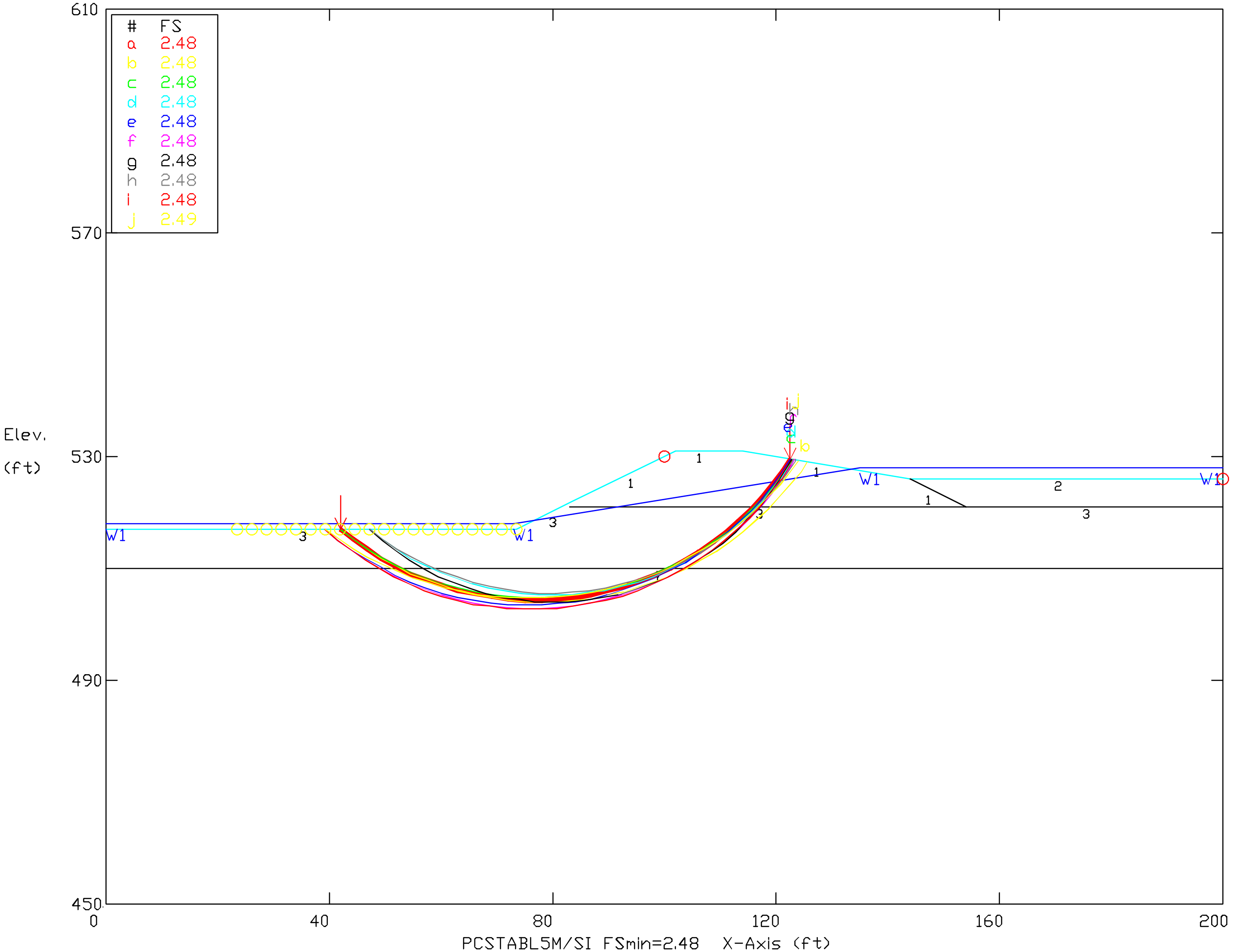


PCSTABL5M/SI FSmin=3.19 X-Axis (ft)

Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	130	130	1950	0	0	0	W1
2 Ash	120	120	0	25	0	0	W1
3 Clay	125	125	900	0	0	0	W1
4 Sand	125	125	0	35	0	0	W1

BSG - Upper to Lower Ash Pond Dike EQ (.105 & -.070) & Normal Upper Pond

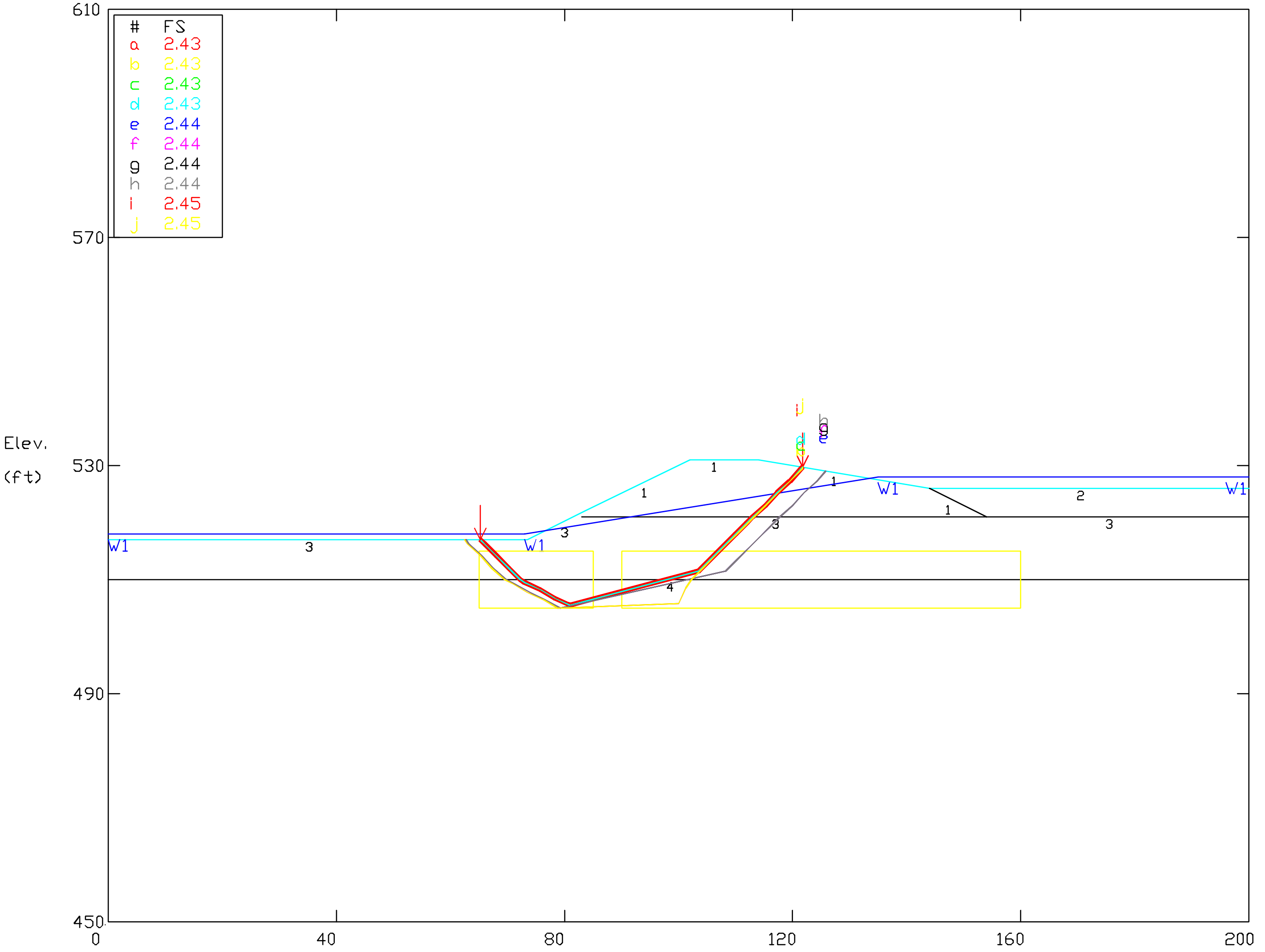
Ten Most Critical. E:BSG40CEQ.PLT 04-25-16 5:06pm



Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Dike	130	130	1950	0	0	0	W1
2	Ash	120	120	0	25	0	0	W1
3	Clay	125	125	900	0	0	0	W1
4	Sand	125	125	0	35	0	0	W1

BSG - Upper to Lower Ash Pond Dike EQ (.105 & -.070) & Normal Upper Pond

Ten Most Critical. E:BSG40BEQ.PLT 04-25-16 5:13pm



PCSTABL5M/SI FSmin=2.43 X-Axis (ft)

Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	130	130	1950	0	0	0	W1
2 Ash	120	120	0	25	0	0	W1
3 Clay	125	125	900	0	0	0	W1
4 Sand	125	125	0	35	0	0	W1

Appendix G

Updated Closure Plan (November 2020)

Closure Plan for Existing CCR Surface Impoundments – Amendment No. 1

Ash Seal Pond
Main Ash Pond
Economizer Pond
Upper Ash Pond

Burlington Generating Station
4282 Sullivan Slough Road
Burlington, Iowa 52601

Prepared for:

Interstate Power and Light Company
4282 Sullivan Slough Road
Burlington, Iowa 52601

SCS ENGINEERS

25219168.00 | November 12, 2020

2830 Dairy Drive
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PE CERTIFICATION

LICENSED PROFESSIONAL ENGINEER
ERIC J. NELSON
23136
IOWA

11/12/20

I, Eric J. Nelson, hereby certify the following:

- This Closure Plan meets the requirements of 40 CFR 257.102(b)(1)
- The final cover system described in this Closure Plan meets the design requirements in 40 CFR 257.102(d)(3)

The Closure Plan was prepared by me or under my direct supervision, and I am a duly licensed Professional Engineer under the laws of the State of Iowa.

11/12/2020

(signature) (date)

Eric J. Nelson

(printed or typed name)

License number 23136

My license renewal date is December 31, 2020.

Pages or sheets covered by this seal:

All pages

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1.0 INTRODUCTION AND PROJECT SUMMARY

On behalf of Interstate Power and Light Company (IPL), SCS Engineers (SCS) has prepared this updated Closure Plan for the coal combustion residual (CCR) units at the Burlington Generating Station (BGS) as required by 40 CFR 257.102(b).

40 CFR 257.102(b) *"Written closure Plan – (1) Content of the plan. The owner or operator of a CCR unit must prepare a written closure plan that describes the steps necessary to close the CCR unit at any point during the active life of the CCR unit consistent with recognized and generally accepted good engineering practices. The written closure plan must include, at a minimum, the information specified in paragraphs (b)(1)(i) through (vi) of this section."*

The BGS facility includes four active, unlined CCR units that are subject to the requirements of 40 CFR 257.102 and included in this closure plan. The CCR units include:

- Ash Seal Pond
- Main Ash Pond
- Economizer Ash Pond
- Upper Ash Pond

Figure 1 shows the site location. **Figure 2** shows the site layout and location of the four CCR surface impoundments. IPL is currently evaluating closure of the CCR surface impoundments using a hybrid approach that includes a combination of CCR removal, consolidation within the CCR surface impoundment limits, and in-place closure with a cap. CCR will be capped with a final cover system that meets the requirements of 40 CFR 257.102. IPL is currently in the process of finalizing studies to support their remedy selection per 40 CFR 257.97. Once a final remedy is selected, IPL will develop design plans and obtain permits/approvals from the State of Iowa to close the CCR surface impoundments. Additional information on each CCR surface impoundment is provided in the sections that follow.

1.1 ASH SEAL POND

The Ash Seal Pond is located south of the plant and adjacent to the Main Ash Pond (**Figure 2**). The Ash Seal Pond was constructed as the original primary ash settling pond at BGS. Under certain operational circumstances, water containing CCR can be temporarily redirected from the Main Ash Pond into the Ash Seal Pond. The surface impoundment is approximately 6.5 acres in size.

1.2 MAIN ASH POND

The Main Ash Pond is located west of the Ash Seal Pond and southwest of the plant. The impoundment is dredged regularly and bottom ash is stockpiled within the footprint of the surface impoundment to dewater. The bottom ash is periodically shipped off site for beneficial reuse as a feedstock in the production of cement. A hydrated fly ash stockpile is also located within the limits of the Main Ash Pond. The hydrated fly ash aggregate is managed under the tradename "Pozzostone" and is removed from the stockpile and the Main Ash Pond on occasion for beneficial use projects, as appropriate, under approvals obtained from the Iowa Department of Natural Resources (IDNR). Currently the pond receives the following waste streams:

- Sluiced bottom ash
- Ash seal system water
- Low-volume waste water from the plant

The Main Ash Pond outfall discharges to the Upper Ash Pond. The Main Ash Pond is approximately 20 acres in size.

1.3 ECONOMIZER ASH POND

The Economizer Ash Pond is located within the original footprint of the Upper Ash Pond and located north of the Main Ash Pond and northwest of the plant. The surface impoundment was constructed on top of the existing CCR in the Upper Ash Pond to receive the following waste streams:

- Sluiced economizer ash
- Low-volume flows from:
  - Water treatment sumps
  - Storm water vault
  - Oil-water separator effluent (via the storm water vault)
  - Various storm drains throughout the plant (via the storm water vault)

The Economizer Ash Pond also drains to the Upper Ash Pond. The surface impoundment is approximately 13 acres in total area but only has a small area of impounded water (approximately 0.4 acre).

1.4 UPPER ASH POND

The Upper Ash Pond is located west of the plant and north of the Main Ash Pond. The Upper Ash Pond receives water from the Main Ash Pond and the Economizer Pond. The Upper Ash Pond originally spanned approximately 28 acres, but with the Economizer Ash Pond constructed within the limits, it reduced the Upper Ash Pond area to approximately 15 acres. The Upper Ash Pond discharges to the Lower Pond, a non-CCR surface impoundment, which then discharges to the Mississippi River in accordance with conditions and limits defined in a National Pollutant Discharge Elimination System (NPDES) Individual Permit 2900101 issued by the IDNR

2.0 PROPOSED CLOSURE PLAN NARRATIVE

40 CFR 257.102(b)(1)(i) *"A narrative description of how the CCR unit will be closed in accordance with this section."*

The CCR surface impoundments at BGS will be closed by a combination of CCR removal, consolidation within the CCR surface impoundment limits, and in-place closure with a cap. Clean closure and final cover areas will be determined during final design.

The four CCR surface impoundment closures will meet the requirement of the Federal CCR Rule and State Regulations. The closure will include the following tasks:

- Dewatering of ponds, where required to meet 40 CFR 257.102(d)(2)(i).
- Potential clean excavation of some surface impoundments or portions of surface impoundments.
- Export of stockpiled material into beneficial uses, when economic conditions and opportunities are favorable.
- Consolidation of CCR from clean closure areas into select impoundment areas to establish final cover subgrade elevations.
- Stabilization of CCR to meet the requirements of 40 CFR 257.102(d)(2)(ii).
- Capping of CCR material with a final covers system per 40 CFR 257.102(d)(3).

- Establishing final grades to preclude ponding storm water on the cap.
- Direct non-contact storm water drainage off the cap.
- Restoration of all areas disturbed during construction.

Slopes and final grades may vary if settlement occurs in the fill material during material placement and grading, or the estimated fill material volumes are different than what is estimated. Final grades will be designed to provide flexibility to accommodate these changes. Side slopes will be able to be flattened or steepened, but will not be steepened in excess of 4H:1V or flattened to less than 2 percent (outside the drainage swales).

CCR and accumulated sediment will be consolidated within the boundary of all or portions of some surface impoundments, and the area will be closed by covering the CCR within the final cover system described in Section 3.0.

3.0 FINAL COVER SYSTEM AND PERFORMANCE

40 CFR 257.102(b)(1)(ii). *"If closure of the CCR unit will be accomplished through removal of CCR from the CRR unit, a description of the procedures to remove the CCR and decontaminate the CCR unit in accordance with paragraph (c) of this section."*

"(c) Closure by removal of CCR. An owner or operator may elect to close a CCR unit by removing and decontaminating all areas affected by releases from the CCR unit. CCR removal and decontamination of the CCR unit are complete when constituent concentrations throughout the CCR unit and any areas affected by releases from the CCR unit have been removed and groundwater monitoring concentrations do not exceed the groundwater protection standard established pursuant to 257.95(h) for constituents listed in appendix IV to this part."

Portions of the CCR surface impoundments to be closed by removal of CCR will either be dewatered with CCR removed mechanically (e.g., with an excavator) or dredged hydraulically while the water in the impoundment remains. All dewatering discharges, whether from pumping or hydraulic dredging, will be treated to meet the discharge limits established in the individual NPDES permit for BGS. Treated water will be discharged via existing Outfall 001, which is located where the Lower Pond discharges to the Mississippi River.

40 CFR 257.102(b)(1)(iii). *"If closure of the CCR unit will be accomplished by leaving CCR in place, a description of the final cover system, designed in accordance with paragraph (d) of this section, and the methods and procedures to be used to install the final cover. The closure plan must also discuss how the final cover system will achieve the performance standards specified in paragraph (d) of this section."*

"(d) Closure performance standard when leaving CCR in place.

(1) The owner or operator of a CCR unit must ensure that, at a minimum, the CCR unit is closed in a manner that will:

(i) Control, minimize or eliminate, to the maximum extent feasible, post-closure infiltration of liquids into the waste and releases of CCR, leachate, or contaminated run-off to the ground or surface waters or to the atmosphere;"

The final cover system design will minimize or eliminate infiltration, as further described below.

(ii) Preclude the probability of future impoundment of water, sediment, or slurry;

The final cover system will meet these criteria, as further described below.

(iii) Include measures that provide for major slope stability to prevent the sloughing or movement of the final cover system during the closure and post-closure care period;

The final cover system will be designed to provide slope stability and to prevent sloughing or movement during the closure and post-closure care period. Stability of the final cover system will be assessed as part of the final cover design for state approvals once state requirements for the final cover system are determined.

(iv) Minimize the need for further maintenance of the CCR unit; and

Maintenance of the final cover will be minimized by the establishment of vegetative cover and the erosion control systems, which are further described below.

(v) Be completed in the shortest amount of time consistent with recognized and generally accepted good engineering practices."

All closure activities for the CCR units at BGS must be completed by October 17, 2023, per 40 CFR 257.103(f)(2)(iv)(A), pending the USEPA's approval of the CCR surface impoundment operating extension beyond April 11, 2021, as requested by IPL according to 40 CFR 257.103(f)(3).

"(2) Drainage and stabilization of CCR surface impoundments. The owner or operator of a CCR surface impoundment or any lateral expansion of a CCR surface impoundment must meet the requirements of paragraphs (d)(2)(i) and (ii) of this section prior to installing the final cover system required under paragraph (d)(3) of this section."

(i) Free liquids must be eliminated by removing liquid wastes or solidifying the remaining wastes and waste residues.

Free liquids will be dewatered from the pond and remaining waste will be mixed with dry CCR or otherwise adequately stabilized prior to final cover system placement.

(ii) Remaining wastes must be stabilized sufficiently to support the final cover system.

The remaining wastes will be stabilized prior to final cover system placement.

"(3) Final cover system"

The final cover system (**Figure 2**) for the four CCR surface impoundments will include the following, at a minimum, from the bottom up:

- Eighteen-inch-thick soil infiltration layer (compacted low-permeability soil)
- Six-inch-thick vegetative soil layer

This final cover will meet the minimum requirements of 40 CFR 257.102(d)(3)(i)(A) through (D) as follows:

- Per 257.102(d)(3)(i)(A), the final cover system will include an 18-inch soil layer with a permeability of $1x10^{-5}$ centimeters per second (cm/sec) or less. The permeability of the proposed final cover system is less than the permeability of the natural subsoils under the pond identified during facility design, as documented in the March 2018 "CCR Surface Impoundment History of Construction" prepared by Hard Hat Services, for the BGS facility. There is no liner system present in any of the surface impoundments.

- Per 257.102(d)(3)(i)(B), the cover system will provide at least 18 inches of earthen material to minimize infiltration.

- Per 257.102(d)(3)(i)(C), erosion of the final cover system will be minimized with a vegetative soil layer with a minimum of 6 inches of un-compacted rooting zone material.

- Per 257.102(d)(3)(i)(D), the design of the final cover system will minimize disruptions to the final cover system and is expected to be stable, based on currently available information about the site and the materials that will be consolidated under the final cover system. The stability of the final cover system will be re-assessed and confirmed during final design once state requirements are determined.

- The design of the final cover will accommodate settling and subsidence of the CCR fill below the cover. The CCR will be placed and compacted prior to final cover placement. The final cover system will be designed with minimum and maximum slopes that will accommodate settlement and minimize disruptions to the cover.

All final cover materials will be tested to confirm they meet the required specifications, and construction will be overseen and documented by a licensed professional engineer. Final cover soil layers will be checked for thickness. All areas will be restored after final cover is placed. Vegetation will be monitored and maintained.

4.0 MAXIMUM INVENTORY OF CCR

40 CFR 257.102(b)(1)(iv). *"An estimate of the maximum inventory of CCR ever on-site over the active life of the CCR unit."*

The estimated maximum inventory of CCR ever on-site in the impoundments, over the active life of the impoundments, is approximately 1,319,065 cubic yards (cy). This is the estimate volume of CCR currently present in the surface impoundments. The following are the estimated CCR volumes for each impoundment:

- Ash Seal Pond – approximately 108,800 cy
- Main Ash Pond – approximately 487,100 cy
- Economizer Ash Pond – approximately 535,400 cy
- Upper Ash Pond – approximately 187,800 cy

These estimates are based on in-place survey, borings, and material test data obtained during geotechnical investigations of the CCR surface impoundments conducted in 2019 and 2020.

5.0 LARGEST AREA OF CCR UNIT REQUIRING FINAL COVER

40 CFR 257.102(b)(1)(v). *"An estimate of the largest area of the CCR unit ever requiring a final cover as required by paragraph (d) of this section at any time during the CCR unit's active life."*

If no clean closure areas are determined during final design, the estimated largest area of final cover would be approximately 55 acres. This number is expected to decrease with portions of the CCR surface impoundments being closed by removal, or if any one surface impoundment is capped independently of the others. Each pond has the following surface areas based on their geometry:

- Ash Seal Pond – approximately 6.5 acres
- Main Ash Pond – approximately 20 acres
- Economizer Ash Pond – approximately 13 acres
- Upper Ash Pond – approximately 15 acres

The surface impoundments are delineated by the berms and access roads.

6.0 SCHEDULE OF SEQUENTIAL CLOSURE ACTIVITIES

40 CFR 257.102(b)(1)(vi). *"A schedule for completing all activities necessary to satisfy the closure criteria in this section, including an estimate of the year in which all closure activities for the CCR unit will be completed."*

The preliminary schedule for closure of the four surface impoundments is provided in **Appendix A.**

7.0 COMPLETION OF CLOSURE ACTIVITES

40 CFR 257.102(f)(1). *"Except as provided for in paragraph (f)(2) of this section, the owner or operator must complete closure of the CCR unit:*

(i) *For existing and new CCR landfills and any lateral expansion of a CCR landfill, within six months of commencing closure activities."*

This does not apply to any of the four surface impoundments.

(ii) *"For existing and new CCR impoundments and any lateral expansion of a CCR surface impoundment, within five years of commencing closure activities."*

Closure of the four units will be completed by October 17, 2023.

40 CFR 257.102(f)(3). *"Upon completion, the owner or operator of the CCR unit must obtain a certification from a qualified professional engineer verifying that closure has been completed in accordance with the closure plan specified in paragraph (b) of this section and the requirements of this section."*

A qualified professional engineer will oversee CCR removal and final cover construction. The engineer will verify CCR removal, verify final cover materials and methods, and oversee material testing. At the end of construction, the engineer will provided a report summarizing and documenting construction and will certify compliance with the requirements.

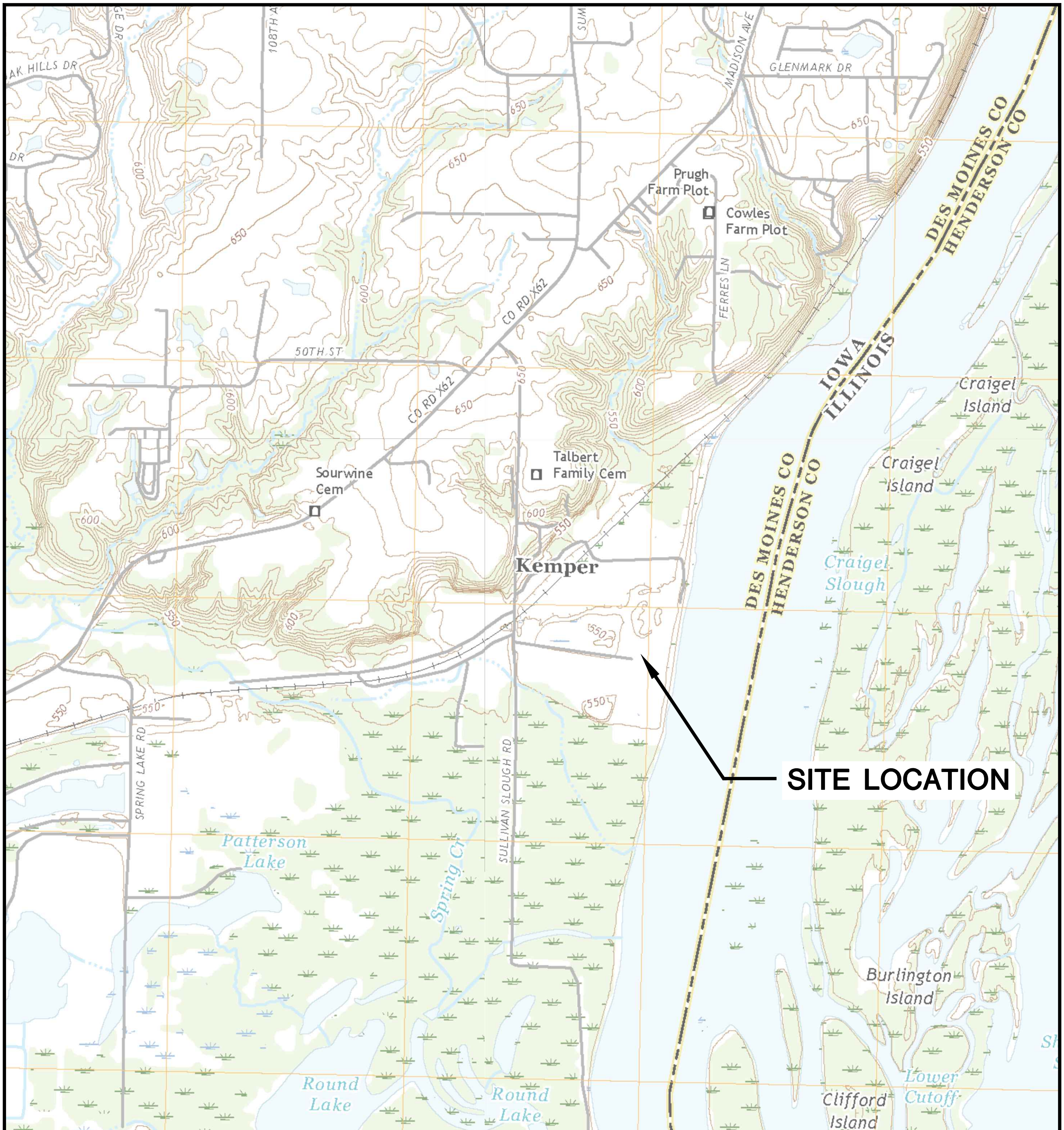
8.0 REFERENCES

40 CFR Part 257, Subtitle D – Environmental Protection Agency Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities.

Hard Hat Services, 2018, CCR Surface Impoundment History of Construction, Burlington Generating Station, Interstate Power and Light Company, March 6, 2018, Revision 1.

Sargent & Lundy, 2016, Closure Plan for Existing CCR Surface Impoundments, Burlington Generating Station, Interstate Power and Light Company, July 18, 2016.

Figures



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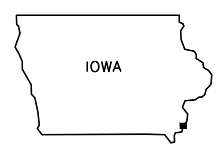
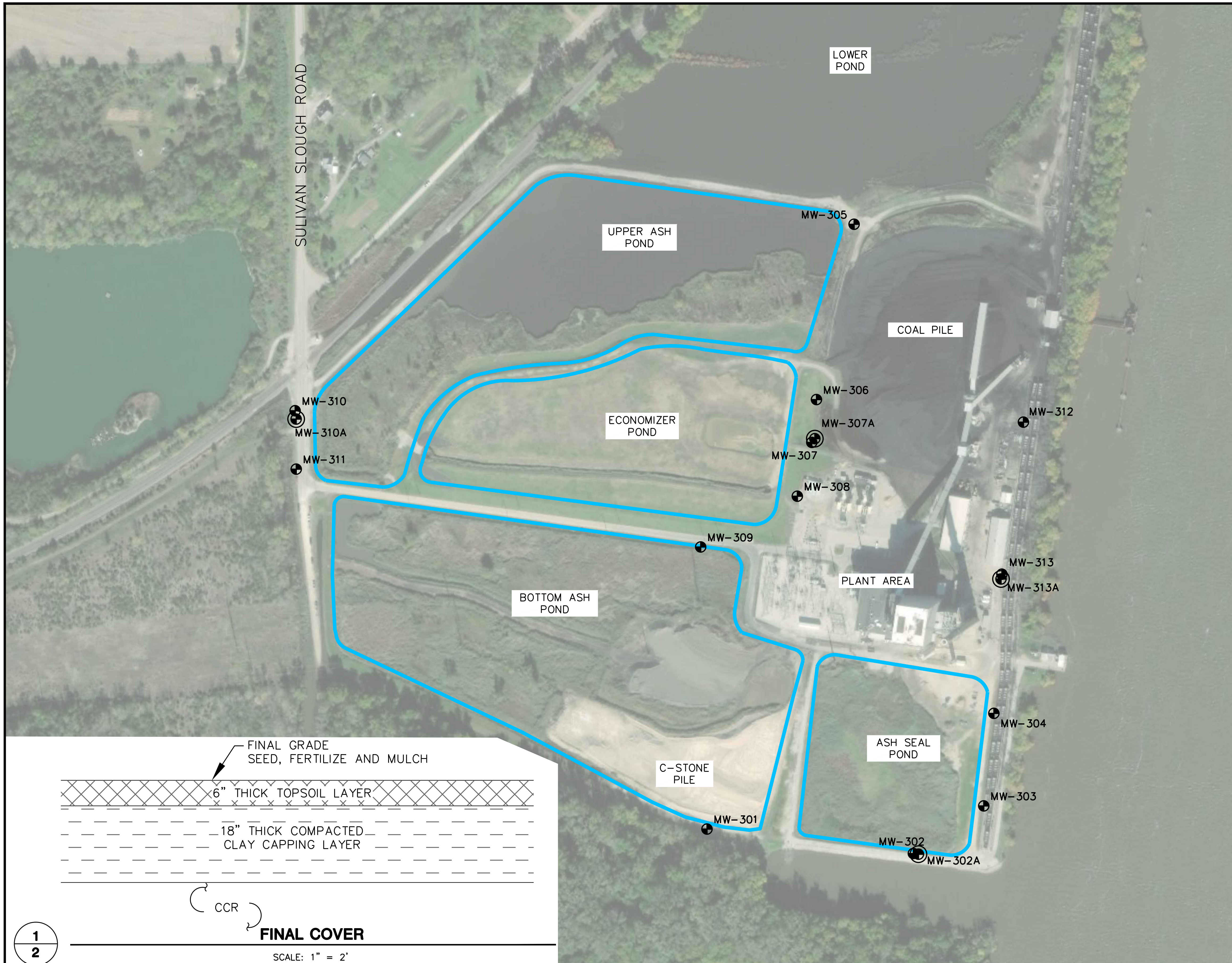
LOMAX QUADRANGLE
ILLINOIS / IOWA–DES MOINES CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
2018
SCALE: 1" = 2,000'



CLIENT	INTERSTATE POWER AND LIGHT 4282 SULLIVAN SLOUGH ROAD BURLINGTON, IOWA 52601	SITE	BURLINGTON GENERATING STATION 4282 SULLIVAN SLOUGH RD BURLINGTON, IA 52601	SITE LOCATION MAP	
PROJECT NO.	25219168.00	DRAWN BY:	RJG	ENGINEER: SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	FIGURE
DRAWN:	09/09/19	CHECKED BY:	PG		1
REVISED:	09/28/19	APPROVED BY:	EJN 11/12/2020		

I:\2521□16□.00\Drawings\1□Site Location Map.dwg, □/2□/2020 10:1□:2□ AM



LEGEND

- EXISTING CCR RULE MONITORING WELL
- EXISTING CCR RULE PIEZOMETER
- CCR UNITS

NOTES:

1. MONITORING WELLS MW-303 THROUGH MW-308 WERE INSTALLED BY CASCADE DRILLING, LLP. UNDER THE SUPERVISION OF SCS ENGINEERS ON DECEMBER 15-17, 2015.
2. MONITORING WELLS MW-301, MW-302, AND MW-309 THROUGH MW-311 WERE INSTALLED BY DIRECT PUSH ANALYTICAL SERVICES CORP. UNDER THE SUPERVISION OF SCS ENGINEERS FROM FEBRUARY 29, 2016 TO MARCH 1, 2016.
3. MONITORING WELLS MW-312 AND MW-313 WERE INSTALLED BY ROBERTS ENVIRONMENTAL DRILLING IN MAY 2019.
4. 2018 AERIAL PHOTOGRAPH SOURCES: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA FSA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY.

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SCALE: 1" = 300'

PROJECT NO.	25220081.00	DRAWN BY:	RJG
DRAWN:	11/14/2019	CHECKED BY:	PG
REVISED:	09/29/2020	APPROVED BY:	EJN 11/12/2020

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BURLINGTON, IOWA 52601

SITE: INTERSTATE POWER AND LIGHT
BURLINGTON GENERATING STATION
BURLINGTON, IOWA

SITE PLAN

FIGURE
2

Appendix A

Closure Schedule

Estimated Pond Closure Schedule
Burlington Generating Station
Iowa Power and Light Company

ID	Task Name	Duration	Start	Finish
1	Planning/Engineering	489 days	Wed 8/7/19	Mon 6/21/21
2	Ash Seal Pond Closure Engineering	45 days	Sun 11/1/20	Thu 12/31/20
3	Permitting	324 days	Fri 1/1/21	Wed 3/30/22
4	Ash Seal Pond Closure Permitting	86 days	Fri 1/1/21	Fri 4/30/21
5	State Sanitary Disposal Project Permit	103 days	Wed 4/21/21	Fri 9/10/21
6	State/Federal Joint Application	165 days	Wed 4/21/21	Tue 12/7/21
7	State/Local Erosion Control Permit	35 days	Thu 2/10/22	Wed 3/30/22
8	Procurement	284 days	Mon 3/1/21	Thu 3/31/22
9	Ash Seal Pond Closure Procurement	45 days	Mon 3/1/21	Fri 4/30/21
10	Remaining CCR Surface Impoundment Closure Procurement	181 days	Thu 7/22/21	Thu 3/31/22
11	Closure Construction	642 days	Mon 5/3/21	Tue 10/17/23
12	Ash Seal Pond Closure	111 days	Mon 5/3/21	Mon 10/4/21
13	Remaining CCR Surface Impoundment Closure (Assumes No Winter Construction Dec 1 to Mar 31)	403 days	Fri 4/1/22	Tue 10/17/23