Ameren

Ameren Services

August 2, 2013

Steve Nightingale, P.E.
Manager, Permits Section, Bureau of Land
Illinois Environmental Protection Agency
1021 North Grand Avenue E.
P.O. Box 19276
Springfield, Illinois 62794-9276

Re: Request for Beneficial Use Determination

Dear Mr. Nightingale:

We are submitting this request[1] for a beneficial use determination for a completed structural fill project at the Duck Creek Power Station located in Canton, Illinois, using coal combustion by-product ("CCB"). On July 29, 2004, a notification was sent to Mr. M. Nechvatal in accordance with 415 ILCS 5/3 135, wherein AmerenEnergy Resources Generating Company ("AERG") advised the Agency that it intended to use CCB as structural fill to construct a railroad embankment and a haul road on its property (the "Rail and Road Project"). The haul road was developed to access the landfill that was proposed for Duck Creek and the rail line is used to deliver coal for the Station. Although the project primarily consisted of the embankment and road, we also identified the need to use CCB for grading adjacent terrain to assure proper drainage and avoiding potential erosion (the "Wedge Project"). The CCB was generated at the E.D. Edwards Power Station located in Bartonville, Illinois and delivered for beneficial use at the Duck Creek Station, both owned by AERG. As indicated in our 2004 letter to Mr. Nechvatal, we began work on the projects in late 2004 completing the Rail and Road Project in 2005.

As you are aware and at the Agency's request, we did submit an application for a beneficial use determination for the yet-to-be-completed Wedge Project on November 2, 2006. The Agency approved our request for a beneficial use determination for that portion of the project on September 30, 2008.

We believe that both the Rail and Road Project and the Wedge Project constitute an engineered application of CCB and do not violate Illinois environmental statutes or regulations. Effective January 1, 2006, 415 ILCS 5/3 135 was amended by P.A. 94-66 to set forth a procedural path for the Agency to make a determination as to whether, similar to the Wedge Project, the Rail and Road

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[1] AERG respectfully requests that the Agency consider this cover letter, the enclosed beneficial use determination request form, and the technical support documents and attachments thereto, as AERG's comprehensive beneficial use determination application.

Project also constitutes a "beneficial use."[2] AERG beneficially used coal combustion by-products from the E.D. Edwards Power Plant as structural fill in a segment of a rail line extension from the Duck Creek Energy Center. AERG's site-specific investigation found that much of the fill was placed over coal mine spoils, and there are no exceedances of applicable groundwater quality standards. The results of this investigation support the conclusion that this beneficial use meets the requirements for a beneficial use determination under Section 3.135(b) of the Illinois Environmental Protection Act and should be approved.

In general, AERG follows the standards established in ASTM E 2277-03 "Standard Guide for Design and Construction of Coal Ash Structural Fills" and believes that the following practices described below either fall within the guidelines or exceed it. Internal specifications were developed for the placement and compaction of the CCB required to complete the projects. The total project length for the Rail and Road Project was approximately 4,800 linear feet and the project used approximately 163,000 cubic yards of CCB. The Rail and Road Project includes an engineered barrier, comprised of a compacted clay and rock cap, which covers the top surface of the embankment. The cap thickness varies from the design thickness to more than 20 feet depending on the location.

This letter also acts as further certification that the CCB have not been mixed with hazardous waste prior to use. The analytical results of samples taken from material that has been place in the Rail and Road Project show that the CCB only exceeds the Class I Groundwater Standards for one contaminant, boron, at one monitoring well location. This monitoring well is within a Class IV area of mine spoil fill. The Board promulgated Class IV standards specifically to apply to groundwater that is already limited in its resource potential. Since the Rail and Road Project is in a Class IV area, controlled by AERG, the boron levels do not pose a threat to human health or the environment.

As explained in AERG's July 29, 2004, letter to the Agency, the use of CCB in this project is appropriate and does not result in harm to human health or the environment. The area in which the CCB was used is industrial/commercial property and appropriate safeguards and management practices were and are used at all times.

If you have any questions or concerns, or would like to meet to discuss this project, please feel free to contact me.

Sincerely,

Susan B. Knowles
Director and Assistant General Counsel

Enclosures

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[2] Section 22.54 provides for the use of beneficial use determinations more generally than Section 3.135(b). Section 22.54(a)(4) has a similar provision that requires that "The management and use of the material will not cause, threaten, or allow the release of any contaminant into the environment, except as authorized by law." Although Section 3.135(b) does not expressly contain the phrase "except as authorized by law" it is implied by the context. It would be an incongruous result if a release or discharge that is consistent with the law and regulations would prevent a beneficial use determination from being approved by the Agency.

Illinois Environmental Protection Agency

Bureau of Land • 1021 N. Grand Avenue E. • P.O. Box 19276
Springfield • Illinois • 62794-9276

OFFICIAL USE ONLY

LPC-PA-27
APPLICATION TO REQUEST A BENEFICIAL USE DETERMINATION

This form must be submitted with an application for a beneficial use in accordance with Section 22.54 of the Illinois Environmental Protection Act (Act). This application must include an original and three (3) photocopies of this form and all supporting information including any reports, plans specifications etc. necessary to fully describe the activities proposed and to demonstrate compliance with the Act. Incomplete applications will be rejected. Please refer to the instructions for further guidance. If there is not enough in the space provided on the form, attach your responses on a separate sheet of paper following the application format. Section 22.54 can be viewed at http://www.ipcb.state.il.us/SLR/TheEnvironmentalProtectionAct.asp.

I. GENERAL INFORMATION

TYPE OF BENEFICIAL USE: Raw Material

LENGTH OF TIME:

We request this beneficial use determination be authorized for 5 years and 0 months. (The Illinois EPA cannot authorize a time period greater than 5 years.)

I.A DESCRIPTION OF THE BENEFICIAL USE:

Use of coal ash as as subgrade material for a rail line. Coal ash is covered with at least 2 feet of compacted fine-grained soils to minimize vertical infiltration of water. See attached as-built set.

II. SITE IDENTIFICATION

A. MATERIAL GENERATOR INFORMATION

Site Name: E.D. Edwards Energy Center
Site # (IEPA): 1430055003
Physical Site Address: 7800 South Cilco Ln.
County: Fulton
City: Bartonville
State: IL
Zip Code: 61607

SITE OWNER	SITE OPERATOR
Name: AmerenEnergy Resources Generating Company	Name: AmerenEnergy Resources Generating Company
Address: P.O. Box 66149 Mail Code 1310	Address: P.O. Box 66149 Mail Code 1310
City: St. Louis State: MO Zip: 63166	City: St. Louis State: MO Zip: 63166
Contact Name: Susan Knowles	Contact Name: Susan Knowles
Phone #: 314-554-3183	Phone #: 314-554-3183

B. MATERIAL USER INFORMATION

Site Name: Duck Creek Energy Center
Site # (IEPA): 0578010002
Physical Site Address: 17751 N. Cilco Road
County: Fulton
City: Canton
State: IL
Zip Code: 61520

SITE OWNER	SITE OPERATOR
Name: AmerenEnergy Resources Generating Company	Name: AmerenEnergy Resources Generating Company
Address: P.O. Box 66149 Mail Code 1310	Address: P.O. Box 66149 Mail Code 1310
City: St. Louis State: MO Zip: 63103	City: St. Louis State: MO Zip: 63103
Contact Name: Susan Knowles	Contact Name: Susan Knowles
Phone #: 314-554-3183	Phone #: 314-554-3183

III. AFFIDAVITS

The following affidavits must be included in your request:

A. An affidavit or certification, from the generator, that the characteristics and method of generation of the material described in the application is accurate. (Original signatures required. Signature stamps or applications transmitted electronically or by facsimile are not acceptable.)

B. An affidavit or certification from the product manufacturer or end user that the description of the storage and use of the material by the manufacturer or end user described in the application is accurate.

C. If applicable, an affidavit or certification from the intermediate management facility such as a marketer that the description of the storage and use of the material by the intermediate facility described in the application is accurate.

IV. DESCRIPTION OF THE PROCESS GENERATING THE MATERIAL:

Coal ash is generated from burning coal at the E.D. Edwards Energy Station. Coal is fed into the power plant boiler and combusted, generating bottom ash, collected at the base of the boiler, and fly ash, collected in the electrostatic precipitator.

V. DESCRIPTION OF LOCATION OF THE INTERMEDIATE STORAGE AND PROCESSING OF THE MATERIAL:

The coal ash was directly transported from the E.D. Edwards Energy Center for use as structural fill for the rail line extension at the Duck Creek Energy Center. See attached technical support document.

VI. JUSTIFICATION THAT THE MATERIAL IS LEGITIMATELY USED BENEFICIALLY AS DEFINED IN SEC. 22.54 (a)(3) OF THE ACT AND THAT IT IS USED AS AN EFFECTIVE SUBSTITUTE FOR A COMMERCIALLY AVAILABLE MATERIAL:

The coal ash was used as structural fill beneath the rail line extension, avoiding mining and importing or granular fill material from other sources. 163,000 cubic yards of coal ash was used for the rail line extension - see attached 12/30/05 "As-Built" file.

VII. IDENTIFICATION OF ANY OF THE HAZARDOUS CONSTITUENTS AND AN EXPLANATION WHY THE CONCENTRATION OF EACH CONSTITUENT AND THE MATERIAL'S MANAGEMENT AND USE WILL NOT NEGATIVELY IMPACT HUMAN HEALTH, SAFETY AND THE ENVIRONMENT:

Leach tests of the material identified antimony, boron, and chromium as constituents of potential concern. Most fill is underlain by mine spoil and there are no exceedances of applicable groundwater quality standards. See attached technical support document.

VIII. CHEMICAL AND PHYSICAL ANALYSIS: (ATTACH TO THE APPLICATION)

IX. IF THE MATERIAL IS APPLIED TO THE LAND, A DISCUSSION OF THE SITE-SPECIFIC GEOLOGY AND THE POTENTIAL FOR CONSTITUENTS OF THE MATERIAL TO MIGRATE TO GROUNDWATER: (ATTACH TO THE APPLICATION)

X. VOLUMES AND TIMEFRAMES FOR USE OF THE MATERIAL AND ANY RESULTING PRODUCTS CONTAINING THE SUBSTITUTE MATERIAL. JUSTIFICATION FOR THE VOLUMES AND TIMEFRAMES FOR STORAGE AND PROCESSING THAT WERE SELECTED: (ATTACH TO THE APPLICATION)

XI. OTHER INFORMATION: (ATTACH TO THE APPLICATION)

XII. SIGNATURES: (Original signatures required. Signature stamps or applications transmitted electronically or by facsimile are not acceptable.)

The application must be signed by the person responsible for using the material or processing the material into a product that is marketable to the general public. All applications shall be signed by the person designated below as a duly authorized representative of the applicant.

1. Corporation – By a principal executive officer of at least the level of vice president.
2. Partnership or Sole Proprietorship – By a partner or proprietor, respectively.
3. Government- by either a principal executive officer or a ranking elected official.

A person is a duly authorized representative of the applicant only if: (1) they meet the criteria above or the authorization has been granted in writing by the person described above; and (2) is submitted with this application.

I hereby affirm that all information contained in this application is true and accurate to the best of my knowledge and belief.

I do herein swear that I am duly authorized representative of the applicant and I am authorized to sign this application form.

APPLICANT

Signature: Date: Aug 2, 2013

Name: Susan B. Knowles

Title: Director and Assistant General Counsel

Company Name: Ameren Services Company

Address: P.O. Box 66149 Mail Code 1310

City: St. Louis State: MO

Zip Code: 63166-6149 Phone: 314-554-3183

ENGINEER

Signature: Date: Aug 2, 2013

Name: Charles R. Henderson

Title: Managing Exec - Ash Mgt & Rail Maintenance - Ameren MO

Address: P.O. Box 66149 Mail Code 611

City: St. Louis State: MO

Zip Code: 63166-6149 Phone: 314-554-3158

Engineer Seal

CHARLES R. HENDERSON
062-048211

"Any person who knowingly makes a false, fictitious, or fraudulent material statement, orally or in writing, to the Illinois EPA commits a Class 4 felony. A second or subsequent offense after conviction is a Class 3 felony. (415 ILCS 5/44(h))"

INSTRUCTIONS FOR BENEFICIAL USE DETERMINATION REQUEST FORM LPC-PA-27
SEPTEMBER 10, 2009

The Illinois EPA will evaluate an application for a beneficial use in accordance with Section 22.54 of the Illinois Environmental Protection Act (Act). If there is not enough in the space provided on the form, please include your information on a separate sheet of paper following the application format and attach it to the application. Section 22.54 can be viewed at http://www.ipcb.state.il.us/SLR/TheEnvironmentalProtectionAct.asp . The following information must be included in your request:

I. This application is limited to requests for a beneficial use determination in accordance with Section 22.54 of the Act. Indicate if the material will be used as a raw material or ingredient, used directly as a product, or used as a catalyst or carrier. Indicate the length of time the beneficial use determination will be needed. Describe the beneficial use. Please note that the Illinois EPA cannot issue a beneficial use determination for a period greater than five years.

II. Identify the location and persons generating the material and using the material. Include proof that the application accurately describes how the material was generated, managed, and will ultimately be used. To do this the application must include the following information:

- A. An affidavit or certification from the generator that the characteristics and method of generation of the material described in the application is accurate.
- B. An affidavit or certification from the product manufacturer or end user that the description of the storage and use of the material by the manufacturer or end user described in the application is accurate.
- C. If applicable, an affidavit or certification from the intermediate management facility such as a marketer that the description of the storage and use of the material by the intermediate facility described in the application is accurate.

III. A description of the process generating the material.

IV. A description of the intermediate storage and processing and end use of the material. This must include a discussion of how the material is managed separately from waste; storage time is minimized; and a description of the methods for collection and storage of the substitute material. This information is required to demonstrate that the material has value and the collection and storage will not negatively impact the environment and that its storage is conducted in a manner that preserves the recyclability of the material. Also discuss how and where the material is currently being specifically handled, stored or disposed when not being used or reused as a product.

V. Justification that the material is used beneficially including comparisons of the physical and chemical properties of the beneficially usable material versus the virgin material it will replace and a discussion of the effectiveness of the use of substitute material versus the virgin product considering the volumes and methods of processing and use. Identify the constituents and their concentrations in the substitute material that are beneficial to the product.

VI. Identification of any of the hazardous constituents identified in 35 Illinois Administrative Code 721 Appendix H that may be present in the material and an explanation why the concentration will not negatively impact human health or the environment when used beneficially as described in the request.

VII. A chemical and physical analysis of the beneficially usable material for all parameters discussed in V and VI above. Also provide a chemical and physical analysis of the virgin material (that will be replaced by the beneficially usable material) for all parameters discussed in V and VI above unless the information is provided from a documented source that has been identified in the application.

VIII. If the material is applied to the land, a discussion of the site-specific geology and the potential for constituents of the material to migrate to groundwater. If groundwater modeling is included, a copy of the modeling results and a copy of the model must be provided to the Illinois EPA for use in verifying the modeling results. Please note that the Illinois EPA cannot issue a beneficial use determination under Section 22.54 for the land application of sludge. Please contact the Bureau of Water Permit Section for instruction on how to apply for authorization for that activity.

IX. Volumes and timeframes for use of the material and any resulting products containing the substitute material. Discuss the market demand for the material and resulting product, the volumes that will be used and the volume of beneficially usable material and resulting product that will be stored versus the time frames needed to collect the beneficially usable material, process it and distribute the end product to demonstrate that the material will be used in a reasonable amount of time, storage times will be minimized and the beneficially usable material and end product will not be abandoned, discharged, deposited, injected, dumped, spilled, leaked or placed into or on any land or water or into any well so that such material or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground waters.

X. Any other information that is necessary to demonstrate that the material is used beneficially and that the resulting use will not cause a violation of the Act or regulations. Discuss other environmental laws and regulations that may apply to the proposed use and how the recycling activity will comply with those laws and regulations.

XI. The application must be signed by a representative of the company that submitted the application. The applicant must be the person that will beneficially use the material or convert the material to a product that can be marketed for use by the general public. The material generator may sign and submit the application if they can demonstrate in the application that they have sufficient control over the beneficial use activity to ensure the beneficial use will be conducted in accordance with the procedures described in the application.

I.A DESCRIPTION OF THE BENEFICIAL USE: (additional text)

IV. DESCRIPTION OF THE PROCESS GENERATING THE MATERIAL: (additional text)

V. DESCRIPTION OF LOCATION OF THE INTERMEDIATE STORAGE AND PROCESSING OF THE MATERIAL: (additional text)

VI. JUSTIFICATION THAT THE MATERIAL IS LEGITIMATELY USED BENEFICIALLY (additional text)

VII. IDENTIFICATION OF ANY OF THE HAZARDOUS CONSTITUENTS (additional text)

AFFIDAVIT OF CHARLES R. HENDERSON

Charles R. Henderson, being first duly sworn upon oath, deposes and states as follows:

1. My name is Charles R. Henderson. I make this affidavit based on my personal knowledge, and if sworn in as a witness I could testify competently to the following facts.

2. I am the Managing Executive - Ash Management and Rail Maintenance for Ameren Missouri. Prior to January 1, 2011I held a similar position within Ameren Fuels and Services (AFS). Prior to 2011, AFS provided services to Ameren Corporation's generation facilities in both Illinois and Missouri. (In early 2011, AFS underwent reorganization and employees were transferred into the operating companies such as AERG and Ameren Missouri.)

3. I was the project manager for the construction of the Duck Creek Rail Project. In that capacity I had primary responsibility for all facets of project management, including the requisition of material; development of construction and engineering drawings; budget management; and the beneficial use of coal combustion material from the E.D. Edwards facility as part of the rail track and road base construction work.

4. The Duck Creek Rail Line and Haul Road project served two business purposes: (1) to create a transportation alternative to the existing BNSF carrier by connecting to a competitor rail line; and (2) provide road access to a utility waste landfill located on plant property. The length of the entire rail track is approximately five (5) miles and the coal combustion material from AERG's E.D. Edwards Energy Center was used to construct the rail and road embankment along the first mile.

5. The first mile of the Rail Line and Haul Road passes through property that was strip mined by a previous owner. Appended to my affidavit are photographs taken after clearing and grubbing activities and depict mine spoils that are prevalent in this area.

6. Approximately 163,000 cubic yards of ash was used to construct the embankment along this first mile. The majority of materials used to construct the embankment came from local borrow clay – including mining spoils. Clay and rock caps were installed on top of the embankment and compacted to 70 % of relative density as set forth in ASTM D4253 and D4254. In addition, one foot of compacted IDOT-approved capping rock was placed on top of the embankment and forms the rail line sub-base and haul road surface. All ash clay and rock fill materials was placed in eight 98) inch to twelve (12) inch lifts and compacted to at least 95% of maximum density as set forth in ASTM D698. Copies of those ASTM standards are appended to my affidavit. Permeability analysis has been performed on both the clay cap and coal combustion materials. The results of that analysis are contained within the report prepared by Natural Resources Technologies (NRT).

7. Throughout the construction process, compaction values were field tested and verified by a third party tester to ensure compliance with the project specification grading requirements. Five (5) test pits were dug along the first mile route in order to verify the elevation of the water table. During construction no ash was placed within three feet of the groundwater table.

8. I have reviewed the materials compiled as part of AmerenEnergy Resources Generating's Beneficial Use Application and such materials are accurate.

Dated: July 31, 2013

CHARLES R. HENDERSON

Subscribed and sworn before me this
31st day of July, 2013.

Julie Donohue
NOTARY PUBLIC

Julie Donohue - Notary Public
Notary Seal, State of
Missouri - St. Louis County
Commission #13753418
My Commission Expires 1/15/2017

My Commission Expires:
15th day of January, 2017

Henderson, Charles R

From: Henderson, Charles R
Sent: Thursday, January 20, 2005 8:23 AM
To: 'ksidwell@ironhustlerexcavating.com'
Cc: 'Glenn T. Hay'; Hof, Glennon P
Subject: RE: Subballast Specification: Duck Creek Build-out

Kenny,

After further review of our subballast specs, we feel the below specs are the correct requirements/criteria for locating a source for the subballast material. We want to have a hard rock surface below the track ballast to ensure the ballast does not become fouled over time. This is what we did at Edwards across the pond if you recall, the Abbingdon quarry rock was used below the Material Service subballast that was placed on top. So, it looks like we need to secure the subballast from Material Service for Duck Creek.

If we have any pond filling at Duck Creek we'll probably look at the Abbingdon quarry and others for this material. Please let me know if you have any questions or need additional information.

Thanks,
Charlie
1/20

> -----Original Message-----
> **From:** Henderson, Charles R
> **Sent:** Monday, January 10, 2005 10:11 AM
> **To:** 'ksidwell@ironhustlerexcavating.com'
> **Cc:** Glenn T. Hay; Hof, Glennon P
> **Subject:** Subballast Specification: Duck Creek Build-out
>
> Kenny,
>
> We looked at some of our past jobs and what our requirements need to be for the subballast rock for the Duck Creek project. Here's the specs that the Duck Creek subballast rock needs to meet, essentially it is an IDOT CA-6 Class B material as follows:
>
> **1. Material Gradation:**
>
> | Sieve Size | Percent Passing Allowable Range |
> |---|---|
> | 1-1/2 inch | 100% |
> | 1 inch | 90 - 100% |
> | 1/2 inch | 60 - 90% |
> | No. 4 | 30 - 56% |
> | No. 16 | 10 - 40% |
> | No. 200 | 4 - 12 % |
>
> **2. Na2SO4 Soundness 5 Cycle:** (AASHTO T104) Maximum Percent Loss = 15%

3. Los Angeles Abrasion: (AASHTO T96) Maximum Percent Loss = 40%

The information that you Faxed to me from Abingdon and Material Service suppliers only listed gradation specs. Please use the above information in your investigation for suitable subballast supply for the project. If you would please ask Material Service and the Abingdon quarry if they can provide material to the above specs. and for what delivered price.

Please let me know if you have any questions or need additional information.

Thanks,
Charlie Henderson
1/10

Charles R. Henderson
Sr. Coal Terminals Executive
Ameren Energy Fuels and Services
P.O. Box 66149, MC-611
St. Louis, MO 63166-6149
(314) 554-3158
(314) 554-4188 (fax)
chenderson@ameren.com

Site-Specific Geology and Potential for Migration in Groundwater: Beneficial Use Determination Duck Creek Energy Center Rail Line Structural Fill

By

Natural Resource Technology, Inc

July 31, 2013

Summary

Section 3.135(b) of the Illinois Environmental Protection Act authorizes the Illinois EPA to make Beneficial Use Determinations (BUDs) “to encourage and promote the utilization of [Coal Combustion Byproducts] CCB in productive and beneficial applications”. Section 3.135(b) requires the applicant to make a demonstration that satisfies the following criteria:

(1) The use will not cause, threaten or allow the discharge of any contaminant into the environment;

(2) The use will otherwise protect human health and the environment; and

(3) The use constitutes a legitimate use of the coal combustion waste as an ingredient or raw material that is an effective substitute for an analogous ingredient or raw material.

Section 3.135(b) provides that a BUD may allow the use of CCB as structural fill (Section 3.135(a)(8)) even if the CCB exceeds Class I groundwater standards for metals when tested utilizing test method ASTM D3987-85. Section 3.35(a)(8) provides that when CCB is used as structural fill it must be done so in an engineered application and covered with 12 inches of soil, unless infiltration is otherwise prevented.

In support of this BUD application, AmerenEnergy Resources Generating Company (AERG), through its contractor, Natural Resource Technology, Inc. performed a site-specific investigation of hydrogeologic conditions along a rail line at the Duck Creek Energy Center constructed in part with coal ash beneficially used as structural fill material. The site investigation included drilling of eight geologic borings, installation of eight monitoring wells, testing for hydraulic conductivity, and groundwater quality sampling for leachate constituents previously determined to have concentrations higher than Class I groundwater quality standards. The primary conclusion of this assessment is that there are no current or potential adverse effects to human health and the environment resulting from this beneficial use application. Other findings of this site-specific investigation indicated:

1) The portion of the rail line containing coal ash fill extends nearly 4,800 feet. The northern 1,000 feet overlays native silty-clay soils, and the southern 3,800 feet overlays mine spoil. Accordingly, the applicable groundwater classification will differ depending upon whether a groundwater sample is taken in a native soil or mine spoil area.

2) Groundwater flows east towards the Duck Creek reservoir.

3) There were no exceedances of Class I groundwater quality standards for the tested constituents in groundwater samples from monitoring wells screened in native soils.

4) There were no exceedances of Class IV groundwater quality standards for monitoring wells screened in mine spoil fill.

5) There is no current or potential future groundwater usage on the property, which is owned and controlled by AERG. Background groundwater quality in the mine spoils is poor, as indicated by a sulfate concentration of 1,500 mg/L in a background monitoring well, precluding potential future potable use of this groundwater.

Introduction

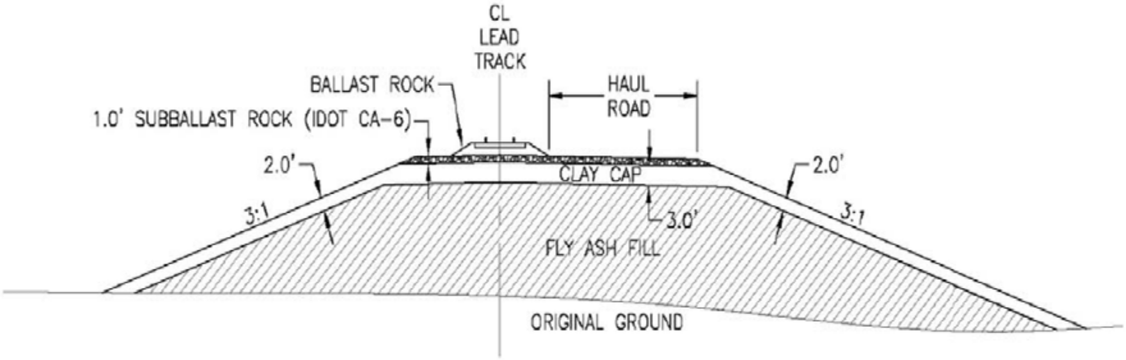
AERG beneficially used coal combustion products from the E.D. Edwards Power Plant as structural fill in a segment of a rail line extension from the Duck Creek Energy Center connecting to the Keokuk Junction Railway (Figure 1). The rail line extension was completed between September 2004 and October 2005. The rail line was built to deliver coal to the Duck Creek Energy Center; the portion of the embankment filled with coal ash is also overlain with a road that is used to access the Duck Creek Energy Center landfill, which was permitted by the Agency's Bureau of Land.

Rail Line Construction

Portions of the rail line are constructed on an embankment built using compacted fly ash as a core material (see illustration below). Prior to construction, five test pits were excavated to determine depth to groundwater along the right-of-way. Test pit stations and water level measurements are listed below. The rail line was constructed so that no coal ash would be placed within 3 feet of the measured groundwater elevations.

Test Pit #	Rail Station Location	Water Elevation
1	23+92.96	597.90
2	30+20.83	Dry at 589.72
3	35+67.54	Dry at 578.72
4	44+16.63	585.91
5	49+97.09	588.85

An engineered barrier, comprised of rock cap overlying at least 3 feet of clay covers the top surface of the embankment. The sloped sides of the embankments have at least 2 feet of compacted clay covered with topsoil and vegetation. The original design plans estimated that 230,000 cubic yards of coal ash would be beneficially used in the construction project; however, the final volume was 163,000 cubic yards. As a result, some sections along the rail line contain less coal ash and more compacted clay than depicted below (refer to the as-built package attached to the BUD application).



Quality control testing performed during construction included:

- All ash, clay, and rock fill materials were placed in 8 to 12 inch lifts.
- Compaction of all clay and ash fills was to at least 95 percent of maximum density as determined by ASTM D698.
- Compaction of all rock fills was to 70 percent of relative density as determined by ASTM D4253 and D4254.
- Compaction values were field tested and verified by a third party tester throughout the construction work to ensure that the grading contractor met the project design and construction specification requirements.

Post-construction, in 2010 Ameren advanced four borings within 6 feet of the centerline of the rail line at stations 17+00, 22+00, 23+50, and 35+00 (Attachment F). These borings encountered between 3 and 5 feet of clay overlying coal ash. Hydraulic conductivity tests performed on two undisturbed clay samples using ASTM D-5084 indicated that the as-built hydraulic conductivity of the compacted clay is very low (1.84×10^{-7} to 3.36×10^{-7} cm/s). These hydraulic conductivity values were determined five years after placement, indicating that weathering has not substantially degraded the cover. The compacted ash material also yielded low hydraulic conductivity values (7.56×10^{-6} to 2.56×10^{-5} cm/s).

Geographic Setting

The rail line is located in a sparsely populated rural area (Figure 1). The nearest dwelling is more than one-half mile to the northwest. Land use to the northwest is agricultural, while land use in all other directions is either former coal mine or industrial. The property immediately surrounding the rail line belongs to the Duck Creek Energy Center.

Coal was strip mined in the area surrounding the Duck Creek facility between 1937 and 1984 (Hanson, 2010). The result of past mining operations is evidenced by the hummocky surface, large impoundments, and small water features evident on Figure 1. Confirmatory information from the Illinois State Geological Survey (ISGS) shows the extents of historic mining (Figure 2) and indicates a majority of the rail line extension was constructed in a previously mined area. A topographic survey completed prior to construction indicated surface elevations ranged from less than 600 feet to more than 650 feet along the rail line extension (Design Nine, Inc. 2004). Active mining no longer occurs within the property boundary of the Duck Creek Energy Center.

Monitoring Well Installation, Sampling, and Testing Activities

Site specific hydrogeology and groundwater quality were evaluated through installation and sampling of six monitoring wells (GS1 through GS6) along the rail line and two background wells to the west and east (wells GS7 and GS8, respectively).[1] The monitoring wells were constructed between April 22 and 26, 2013 and the locations are shown on Figure 3. Monitoring wells GS3, GS4, and GS7 were completed in undisturbed soils, and wells GS1, GS2, GS5, GS6, and GS8 were completed in mine spoils (Figure 4). The monitoring well boreholes were drilled using hollow-stem auger drilling methods and the wells were constructed of 2-inch inside diameter, schedule 40 PVC in accordance with industry standards. Monitoring well construction details are summarized in Table 1 and NRTs standard operating procedure (SOP) for well installation and development is included in Attachment A.

The monitoring wells were developed, sampled, and hydraulically tested between April 29 and May 2, 2013. The monitoring wells were developed using a bailer to surge the wells and a pump to remove the water and accumulated sediment. Following development, the wells were sampled using low-flow methods while monitoring field parameters for stabilization. A follow-up sample was collected from GS5 on June 5, 2013 to confirm concentrations observed in the original sample. Slug tests were completed at each well to assess the hydraulic characteristics of the screened intervals. The well development, sampling, and hydraulic testing were completed to industry standards and the SOPs are included in Attachment A. Other supporting documents are contained in Attachments B, C, and D:

- Attachment B - Boring Logs and Well Completion Reports
- Attachment C - Slug Test Data and Plots
- Attachment D - Laboratory Analytical Reports

Regional Geology

The bedrock stratigraphy generally consists of interbedded shale, siltstone, sandstone, and coal units. According to the United States Geological Survey (USGS, 2012) the geologic units in Fulton County, Illinois are of Pennsylvanian and Mississippian age, and the two most prevalent are the Carbondale and Spoon Formations, which cover 58% and 31% of the county, respectively. Unlithified deposits in the region included fine and course grained sediments of glacial, lacustrine, alluvial, or aeolian origin (Willman, 1975).

Site-Specific Geology

Glacial deposits were encountered along the northern portion of the rail line, and mine spoil was encountered along the central and southern portions. These observations are consistent with the ISGS previously mined areas map. Hanson (2010) also encountered mine spoils in a site investigation at the ash ponds, immediately south of the rail line. Additional observations regarding the mine spoil from the Hanson report include:

- Mine spoils overlying bedrock range from approximately 10 feet to as much as 75 feet in thickness, and these spoils are a mixture of broken bedrock and unlithified materials.

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[1] GS8 is a background well due to its distance (2,300 feet) from the rail line and because it is south and east of a branch of the reservoir where the water surface is at an elevation between 560 and 570 feet—this water surface elevation indicates that groundwater flowing east from the rail line area (water table ~600 feet) will discharge to the branch of the reservoir and will not flow toward GS8.

- The Carbondale Formation is the uppermost bedrock in this area and the depth to bedrock generally decreases to the north and west.

Undisturbed (Northern) Portion of the Fill Area

The northern portion of the fill area (approximately 1,000 feet) is in an area that was not previously mined (Figure 2). The surface materials encountered in this immediate area consist of glacially deposited silts and clays overlain by loess. Hydraulic conductivity in these materials is low, ranging from 8.3×10^{-5} to 4.0×10^{-4} cm/s, with a geometric mean of 1.5×10^{-4} cm/s (Table 2). The low hydraulic conductivity of this formation restricts migration of groundwater, and the abundant clays in the material provides sorption and exchange sites that will further restrict migration of metals in the event of a release from the structural fill.

Previously Mined (Central and Southern) Portion of the Fill Area

The central and southern portion of the rail extension (approximately 3,800 feet) is in a previously mined area (Figure 2). This area is characterized by mine spoils over bedrock. The mine spoils consist of silt and clay overburden mixed with shale fragments. Hydraulic conductivity in these materials is low, ranging from 2.3×10^{-6} to 8.8×10^{-4} cm/s, with a geometric mean of 4.0×10^{-5} cm/s (Table 2). The low hydraulic conductivity of this material restricts migration of groundwater, and the abundant clays from the overburden interspersed in the material provides sorption sites that will further restrict migration of metals in the event of a release from the structural fill.

Site-Specific Hydrogeology

Groundwater Depth and Flow Direction

The depth to water (Table 1) was measured on April 30 to determine the groundwater elevation and flow direction. Groundwater near the structural fill is shallow, less than 13 feet below top of casing, and in most cases less than 10 feet. Groundwater elevation differed by approximately 30 feet between the background wells GS7 (615 feet) and GS8 (585 feet), and by 17 feet (606 to 589 feet) between the six wells along the rail line. In addition, there are seasonal changes in groundwater elevation, as indicated by the difference between elevations measured in April 2013 (606 to 589 feet in monitoring wells along the rail line) to groundwater elevations observed in test pits prior to construction (598 to lower than 579 feet). The high groundwater elevations observed in April 2013 were in response to a wet period during spring of 2013.[2]

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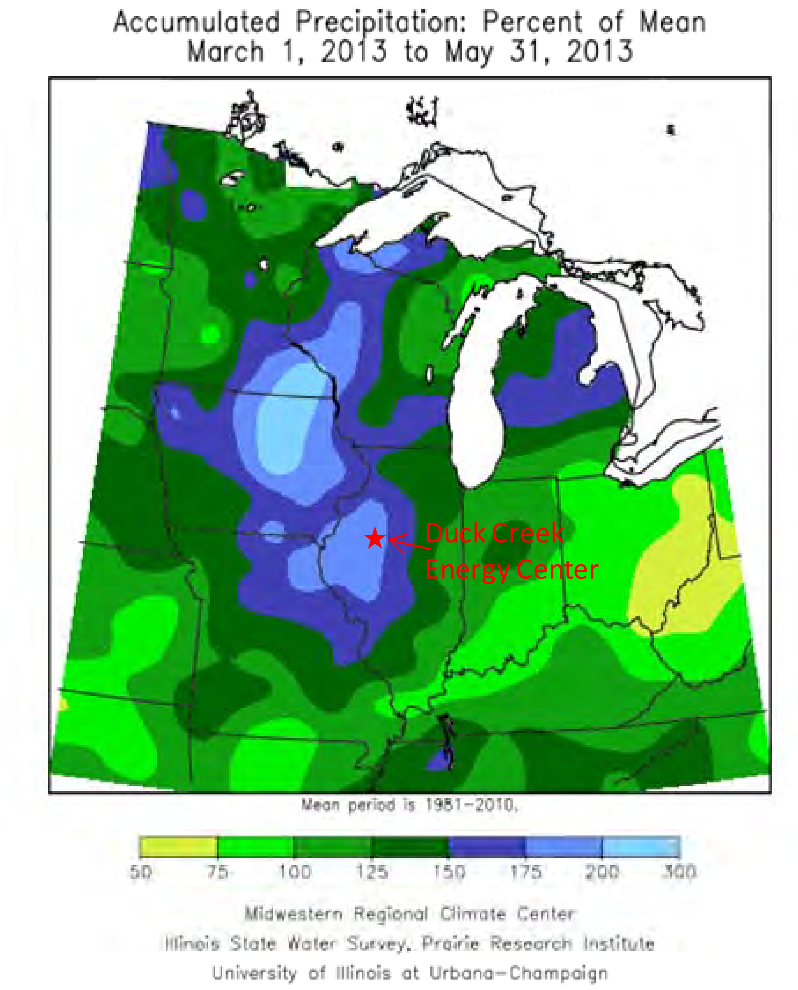
[2] The map depicting precipitation percent of mean is from http://mrcc.isws.illinois.edu/cliwatch/seasons/mam.pperc.png; the map was modified to show the location of the Duck Creek Energy Center.



The highest groundwater levels both prior to construction and in the April 2013 measurements were observed near station 24+00. There is a large pond immediately west of the rail line in this area (Figure 5) which was at elevation 603 feet at the time of the pre-construction survey (refer to as-builts sheet 8), and which may be influencing groundwater elevations near GS2 and GS5.

The groundwater flow direction is from west to east (Figure 5), which is similar to the results reported by Hanson (2010), and consistent with a conceptual site model where groundwater flows toward and ultimately discharges to the Duck Creek reservoir, where the water surface elevation is approximately 560 feet.

Groundwater Resources

There is one log for a domestic water supply well within 2,500 feet of the portions of the ash fill overlying undisturbed soils. This log is for a well located 1,300 feet directly west of the northernmost point of coal ash fill (Figure 5). The well is 24 inches in diameter and draws groundwater from clay at a total depth of 50 feet. Its location was verified by Hanson (2010). However, there is no longer a building or any other sign of human occupation on this parcel, and the current status of the well is uncertain. Assuming this well remains active, there is no potential for it to be impacted in the event of a release from the coal ash fill in the rail line because it is upgradient of the rail line. Furthermore, the low boron concentrations in GS3 and GS7, which are located between the water well and the rail line, indicate no evidence of a release in the direction of the water well. This well is located in native soils, undisturbed by mining operations.

There are no recorded wells located within 2,500 feet of the rail line built in an area underlain by mine spoil. The Duck Creek Energy Center obtains its potable water supply from Canton, IL. Groundwater quality in mine spoil is generally not considered potable.

Water Quality

E.D. Edwards Coal Ash Laboratory Leaching Tests

Leach testing performed on an Edwards coal ash sample collected in 2004 and representative of the coal ash used in the structural fill—which was built in 2004 and 2005—was performed using ASTM Method D3987-85 (NRT 2010). Concentrations of antimony, boron, and chromium in the synthetic leachate were higher than their respective Class I groundwater quality standards (Table 3 and summarized below). These results were similar to leach testing performed on 12 additional Edwards coal ash samples collected in 2008 (Attachment E). The 2008 samples also had boron and antimony exceedances; however, they did not exhibit chromium exceedances and had a silver exceedance. The silver results in the 2008 samples are not representative of coal ash leachate and more likely represent a laboratory anomaly. The 2004 sample is more representative of the ash used as fill in the rail line than the 2008 samples because it was collected at the same time that the rail line fill was placed, and as a result was used as the basis for groundwater sampling. Therefore, antimony, boron, and chromium were analyzed in the groundwater samples. In addition, sulfate was sampled as an indicator of overall water quality within the mine spoils.

Parameter	Analytical Results (mg/L)	Groundwater Class I Quality Standards (mg/L)
Antimony	0.0063	0.006
Boron	6.1	2.0
Chromium	0.12	0.10

Applicable Groundwater Quality Standards

The northern portion of the rail line was built in an area underlain by native soils. Groundwater sample results in this area were compared to Class I groundwater quality standards. The Class I standards apply to samples collected at GS3, GS4, and GS7.

The central and southern portions of the rail line were built in an area underlain by mine spoil. Groundwater sample results were compared to Class IV groundwater quality standards. Under Class IV, 35 Ill. Adm. Code 620.440(c) provides that for groundwater within a previously mined area, the standards for Class II groundwater set forth in Section 620.420 generally apply.[3] The standards for antimony and

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[3] The text of 35 Ill. Adm Code 620.440(c) provides:

> c) For groundwater within a previously mined area, the standards set forth in Section 620.420 must not be exceeded, except for concentrations of TDS, chloride, iron, manganese, sulfates, pH, 1,3-dinitrobenzene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, HMX (high melting explosive, octogen), nitrobenzene, RDX (royal demolition explosive, cyclonite), 1,3,5-trinitrobenzene, or 2,4,6-

chromium are listed in Section 620.420(a)(1) and provided in Table 4. The standard for boron is listed in Section 620.420(a)(2);however, Section 620.420(a)(2) provides that the listed standards do not apply if Section 620.420(a)(3) applies. Section 620.420(a)(3) provides that the standards for any inorganic chemical constituent listed in Section 620.420(a)(2), which includes boron, do not apply within fill material or within the upper 10 feet of parent material under such fill material on a site if, prior to November 25, 1991, surficial characteristics have been altered by the placement of such fill material.[4] Section 620.420(a)(4) defines “fill material” to mean “clean earthen materials, slag, ash, clean demolition debris, or other similar materials.”

The mine spoil fill at the site was placed prior to plant construction in the 1970’s, and prior to November 25,1991. Figure 4 shows how disposal of mine spoils has altered the surficial characteristics of the area. The impact on groundwater quality can be seen in a comparison of the sulfate levels in background wells GS7 (placed in native soils) and GS8 (placed in mine spoil). See Table 4; As a result 35 IAC 620.420(a)(3) applies to samples collected from GS1, GS2, GS5, GS6, and GS8 because these wells monitor groundwater within fill materials.

Groundwater Quality

Groundwater analytical results are presented in Table 4. Concentrations of sulfate and boron were higher in the mine spoil than in the native soils, concentrations of chromium were higher in the native spoils than in the mine spoils, and antimony was not detected in any groundwater samples. The sulfate concentration in background well GS8 was 1,500 mg/L, indicating overall poor groundwater quality in the mine spoil.

There are no exceedances of applicable groundwater quality standards in the monitoring wells along the rail line (Table 4). Boron was detected, and verified in a resample, at a concentration of 8 mg/L in GS5; however, because this monitoring well is within mine spoil fill, there is no numeric standard for boron in this material (35 IAC 620.420(a)(3)).

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trinitrotoluene (TNT). For concentrations of TDS, chloride, iron, manganese, sulfates, pH, 1,3-dinitrobenzene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, HMX, nitrobenzene, RDX, 1,3,5-trinitrobenzene, or 2,4,6-trinitrotoluene (TNT), the standards are the existing concentrations.

[4] The text of 35 Ill. Adm. Code 620.420(a)(3) provides:

> 3) The standard for any inorganic chemical constituent listed in subsection (a)(2) of this Section, for barium, or for pH does not apply to groundwater within fill material or within the upper 10 feet of parent material under such fill material on a site not within the rural property class for which:
>
> A) Prior to November 25, 1991, surficial characteristics have been altered by the placement of such fill material so as to impact the concentration of the parameters listed in subsection (a)(3) of this Section, and any on-site groundwater monitoring of such parameters is available for review by the Agency.
>
> B) On November 25, 1991, surficial characteristics are in the process of being altered by the placement of such fill material, that proceeds in a reasonably continuous manner to completion, so as to impact the concentration of the parameters listed in subsection (a)(3) of this Section, and any on-site groundwater monitoring of such parameters is available for review by the Agency.

The groundwater samples from GS5 were obtained over a wet, relatively short (five-week) period when groundwater levels were relatively high. Further evaluation would be required to determine whether or not the observed boron concentrations at this monitoring well are persistent and exhibit a decreasing or increasing trend.

Review of the as-built sections (23+00 and 24+00) closest to GS5 indicates that the base of coal ash fill in this area is approximately 601 to 605 feet. The water table measured at GS5 was approximately 600 feet, and the water table measured on the opposite (upgradient) side of the rail line at GS2 was 606 feet, indicating that the coal ash fill upgradient of GS5 may have been below the water table in May and early June of 2013. In contrast, test pit 1 at station 23+92.96 (near the centerline of the embankment, prior to construction) indicated a groundwater elevation of approximately 598 feet, indicating a water table below the current base of ash. These observations suggest that periodic events may occur when groundwater intersects the base of ash in the embankment in this area; although further evaluation would be needed to confirm this hypothesis. If groundwater intersects the base of the embankment, then the observed boron concentration in GS5 could reflect short-term, episodic events, occurring during relatively wet periods. Various draining mechanisms could be employed to lower the water table elevation so as to inhibit groundwater from communicating with ash within the embankment during periods of high water table.

Discussion

A site specific investigation of hydrogeology and groundwater quality along the portion of the rail line at the Duck Creek Energy Center where coal ash was beneficially used as a structural fill indicates that the beneficial use project has not adversely affected human health and the environment, nor will it have an adverse impact in the future. Data and observations supporting this conclusion are:

- The rail line was constructed with a compacted clay cap that limits infiltration into the underlying compacted coal ash.

- There are no water supply wells downgradient of the rail line. Groundwater flow beneath the rail line is east toward the Duck Creek Reservoir, which is not used for potable water, on land owned and controlled by Ameren, and there is no potential future use of this groundwater.

- There is no evidence of groundwater impacts along the northern 1,000 feet of the rail line, which is constructed over native clay and silt rich soils.

- The central and southern 3,800 feet of the rail line are underlain by mine spoil, and the mine spoil has leached high sulfate concentrations to the groundwater which makes it unsuitable for potable use.

To the extent the elevated levels of boron observed in one of the six monitoring wells installed within 100 feet of the rail line is attributable to coal ash used within the embankment, such concentrations were observed over a short, wet period when groundwater elevations were relatively high.

The clay cover and compaction of the structural fill material within the embankment minimizes vertical infiltration of water into the fill. To the extent that ash within the embankment is in contact with groundwater during seasonal and short term periods, such contact could be minimized by employing a variety of drainage techniques to lower the elevation of the water table in this area.

Conclusion

AERG beneficially used coal combustion products from the E.D. Edwards Power Plant as structural fill in a segment of a rail line extension from the Duck Creek Energy Center. This site-specific investigation found that much of the fill was placed over coal mine spoils, and there were no exceedances of applicable groundwater quality standards. The results of this investigation support a conclusion that this beneficial use meets the requirements for a BUD determination under Section 3.135(b) of the Illinois Environmental Protection Act.

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Figures

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REVIEWED BY/DATE:
EPK 7/18/13
APPROVED BY/DATE:
BRH 7/22/13

SITE LOCATION MAP

BENEFICIAL USE DETERMINATION
DUCK CREEK ENERGY CENTER
CANTON, FULTON COUNTY, ILLINOIS

PROJECT NO: 2020

FIGURE NO: 1

NATURAL RESOURCE TECHNOLOGY

Y:\Mapping\Projects\20\2020\MXD\BUD\Figure 1_Site Location.mxd Author: tcushman; Date/Time: 7/22/2013, 3:42:21 PM

Surface Coal Mine data obtained from Illinois State Geological Survey (http://www.isgs.illinois.edu/maps-data-pub/coal-maps/coalshapefiles.shtml), accessed on 6/24/2013.
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Y:\Mapping\Projects\20\2020\MXD\BUD\Figure 2_Previously Mined Areas.mxd Author: tcushman; Date/Time: 7/22/2013, 3:41:19 PM

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PREVIOUSLY MINED AREAS

BENEFICIAL USE DETERMINATION
DUCK CREEK ENERGY CENTER
CANTON, FULTON COUNTY, ILLINOIS

PROJECT NO: 2020

FIGURE NO: 2

NATURAL RESOURCE TECHNOLOGY

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Y:\Mapping\Projects\20\2020\MXD\BUD\Figure 3_Site Wells.mxd Author: tcushman; Date/Time: 7/22/2013, 3:40:18 PM

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BRH 7/22/13

SITE WELLS - GS1 THROUGH GS8

BENEFICIAL USE DETERMINATION
DUCK CREEK ENERGY CENTER
CANTON, FULTON COUNTY, ILLINOIS

PROJECT NO: 2020

FIGURE NO: 3

NATURAL RESOURCE TECHNOLOGY

WELL LOCATION
SECTION OF RAIL LINE WITH COAL ASH FILL
RAIL LINE GRADING LIMITS
EXTENT OF SURFACE COAL MINES

Service Layer Credits: Historical Aerial Photos exported from Google Earth on 6/25/2013. Imagery date: 4/6/1999

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BRH 7/22/13

SITE WELLS WITH EXTENT OF COAL MINED AND ASH FILLED AREAS

BENEFICIAL USE DETERMINATION
DUCK CREEK ENERGY CENTER
CANTON, FULTON COUNTY, ILLINOIS

PROJECT NO: 2020

FIGURE NO: 4

NATURAL RESOURCE TECHNOLOGY

Y:\Mapping\Projects\20\2020\MXD\BUD\Figure 4_Site Wells with Extent of Coal Mined and Ash Filled Areas.mxd Author: tcushman; Date/Time: 7/22/2013, 3:39:26 PM

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Y:\Mapping\Projects\20\2020\MXD\BUD\Figure 5_Groundwater Flow Map.mxd Author: tcushman; Date/Time: 7/23/2013, 8:28:24 AM

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EPK 7/18/13
APPROVED BY/DATE:
BRH 7/22/13

GROUNDWATER FLOW MAP
30 APRIL 2013

BENEFICIAL USE DETERMINATION
DUCK CREEK ENERGY CENTER
CANTON, FULTON COUNTY, ILLINOIS

PROJECT NO: 2020

FIGURE NO: 5

NATURAL RESOURCE TECHNOLOGY

Tables

Table 1. Well Construction and April 30, 2013 Groundwater Elevation Information
Duck Creek Rail Line Extension

Well	ISPC Northing (feet)	ISPC Easting (feet)	TOC Elevation (feet)	Ground Elevation (feet)	Well Depth (feet)	Base of Well Elevation (feet)	Depth to Groundwater (4/30/13) (feet)	Groundwater Elevation (feet)
GS1	1,393,568.77	2,345,228.96	606.05	603.61	20.44	585.61	6.45	599.60
GS2	1,394,468.62	2,345,208.76	612.41	610.67	22.04	590.37	6.17	606.24
GS3	1,396,880.48	2,345,234.43	608.72	606.50	25.02	583.70	8.52	600.20
GS4	1,396,872.90	2,345,593.01	601.86	599.70	22.16	579.70	12.70	589.16
GS5	1,394,892.91	2,345,473.04	611.87	610.45	26.82	585.05	11.88	599.99
GS6	1,393,712.70	2,345,458.67	602.77	600.33	22.84	579.93	7.75	595.02
GS7	1,397,057.00	2,344,178.35	620.08	617.96	26.72	593.36	4.72	615.36
GS8	1,394,644.23	2,347,610.14	600.75	598.72	22.03	578.72	15.21	585.54

Notes:
1) TOC is Top of Casing
2) Horizontal Datum is IL State Plane 1983 (CORS96), West Zone 1202 (ISPC)
3) Vertical Datum is NGVD 29
4) Date of Survey: May 1-2, 2013
5) Ameren Survey Control Pt #95: Iron Rod Set in Cone., El. 616.60
Control Point Plant Coords are N 14661.70; E -72.90 and the ISPC Coords are N 1,397,703.93; E 2,345470.97

Table 2. Hydraulic Conductivity Results
Duck Creek Rail Line Extension

Well	Formation	Hydraulic Conductivity (cm/sec)			Typical Formation (Freeze & Cherry, 1979)
		Test 1	Test 2	Average	
Rail Line Extension Wells					
GS1	Mine Spoil	2.4E-04	1.9E-04	2.1E-04	mid-range silt (loess), lower range silty sand
GS2	Mine Spoil	2.3E-06	nt	2.3E-06	upper range glacial till, lower range silt (loess)
GS3	Native	6.5E-04	1.6E-04	4.0E-04	upper range silt (loess), mid-range silty sand
GS4	Native	8.0E-05	8.5E-05	8.3E-05	mid-range silt (loess), lower range silty sand
GS5	Mine Spoil	4.3E-04	1.3E-03	8.8E-04	upper range silt (loess), mid-range silty sand
GS6	Mine Spoil	3.7E-06	nt	3.7E-06	upper range glacial till, lower range silt (loess)
Background Wells					
GS7	Native	1.1E-04	1.1E-04	1.1E-04	mid-range silt (loess), lower range silty sand
GS8	Mine Spoil	6.3E-05	nt	6.3E-05	mid-range silt (loess), lower range silty sand

Notes:
1) Wells that recovered slowly were only tested once, so the Test 1 and Average value listed is the same.
2) "nt" indicates the well was not tested a second time.

Table 3. Analytical Results from ASTM D3987-85 testing
E.D. Edwards Plant Coal Ash
Duck Creek Rail Line Extension

Parameter	Analytical Results (mg/L)	IL Section 620.410 Groundwater Quality Standards for Class I (mg/L)
Antimony	0.0063	0.006
Arsenic	0.012	0.05
Barium	0.80	2.0
Beryllium	<0.001	0.004
Boron	6.1	2.0
Cadmium	0.001	0.005
Chromium	0.12	0.10
Cobalt	<0.002	1.0
Copper	0.0023	0.65
Iron	<0.02	5.0
Lead	<0.001	0.0075
Manganese	<0.001	0.15
Mercury	0.00065	0.002
Nickel	0.0043	0.10
Selenium	0.016	0.05
Silver	0.0049	0.05
Thallium	0.00075	0.002
Zinc	0.023	5.0

Notes:
1) Shading indicates a concentration higher than the Class I standard

Table 4. Groundwater Analytical Results
Duck Creek Rail Line Extension

Well	Sample Date	Formation	Applicable Standard	Concentrations (mg/L)			
				Antimony	Boron	Chromium	Sulfate
35 IAC 620.410 Class I Standards (mg/L)				**0.006**	**2.0**	**0.10**	**400**
Rail Line Extension Wells							
GS3	05/01/13	Native	Class I	<0.0046	0.037	0.0028	86
GS4	05/01/13	Native	Class I	<0.0046	0.013	0.0016	225
Background Wells							
GS7	04/30/13	Native	Class I	<0.0046	0.011	<0.0014	83

Well	Sample Date	Formation[B]	Applicable Standard[A]	Concentrations (mg/L)			
				Antimony	Boron	Chromium	Sulfate
35 IAC 620.410 Class II/IV Standards (mg/L)				**0.024**	**---**	**1.0**	**---**
Rail Line Extension Wells							
GS1	04/30/13	Mine Spoil	Class IV	<0.0046	0.804	<0.0014	491
GS2	05/01/13	Mine Spoil	Class IV	<0.0046	0.058	<0.0014	667
GS5	05/01/13	Mine Spoil	Class IV	<0.0046	7.970	<0.0014	1,820
QC1 (dup)	*05/01/13*	*Mine Spoil*	Class IV	*<0.0046*	*8.140*	*<0.0014*	*1,800*
GS5	06/05/13	Mine Spoil	Class IV	<0.000054	7.630	na	1,800
GS6	05/01/13	Mine Spoil	Class IV	<0.0046	0.104	<0.0014	699
Background Wells							
GS8	05/01/13	Mine Spoil	Class IV	<0.0046	0.095	0.0015	1,530

Notes:

1) There are no concentrations exceeding an applicable groundwater quality standard.
2) QC1 is a duplicate water sample of GS5.
3) na: Parameter was not analyzed in sample.

A) For groundwater in previously mined areas, the sulfate standard is the existing concentration, while Class II numeric standards apply to antimony, boron, and chromium [35 IAC 620.440(c)].

B) According to 35 IAC 620.420(a)(3), Class II standards for boron and sulfate do not apply to groundwater within fill material placed prior to Nov. 25, 1991. Mine spoil fill at the site was placed prior to plant construction in the 1970's. Therefore, 35 IAC 620.420(a)(3) applies to samples from the wells constructed in the mine spoil (GS1, GS2, GS5, GS6, and GS8).

Attachment A

Field Investigation Method
Standard Operating Procedures (SOPs)

Monitoring Well Construction and Development

Groundwater Sampling

Aquifer Testing

MONITORING WELL CONSTRUCTION AND DEVELOPMENT

1.1 Scope and Application

This standard is applicable to construction and development of groundwater monitoring wells.

1.2 Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety (H&S) standard operating procedures (SOPs) when working with potentially hazardous material or with material of unknown origin. Project-specific H&S plans will contain additional practices, if necessary, that are necessary to mitigate project- or site-specific hazards.

Clear all underground utilities, private, commercial, and public in accordance with SOP 07-05-01 prior to commencing sampling activities. Screen each sample location with a metal detector or magnetometer prior to sampling to verify the absence buried metal, such as underground pipes.

1.3 Considerations

The design and installation of permanent monitoring wells involve the drilling of boreholes into various types of geologic formations that exhibit varying subsurface conditions. Designing and installing permanent monitoring wells in these geologic environments may require several different drilling methods and installation procedures. Individual states may have well construction methods and requirements that should be reviewed and incorporated into scope development and well construction to ensure that applicable regulations are satisfied.

The selection of drilling methods and installation procedures shall be based on field data collected during a hydrogeologic site investigation and/or a search of existing data. Each permanent monitoring well shall be designed and installed to function properly throughout the entire anticipated life of the monitoring program.

When designing monitoring wells the following questions shall be considered:

- What are the short- and long-term objectives?
- How long will the monitoring program last?
- What contaminants are to be monitored/ analyses needed?
- What types of well construction materials are to be used/ size of borehole?
- What are the surface and subsurface geologic conditions?
- What aquifer(s) is going to be monitored?
- Over what depth(s) will the well be screened?
- What is the anticipated total depth of the well?
- What are the general site conditions/ drill rig access?
- What are the potential health and safety hazards?
- Are these wells going to serve more than one purpose (i.e., monitoring, pump test, extraction)?

Each of the previous questions can be expanded into many subtopics depending on the complexity of the project. In designing permanent monitoring wells, the most reliable data shall be utilized. Once the data have been assembled and the well design has been completed, a drilling method(s) has to be selected.

1.4 Drilling Methods for Monitoring Well Installation

The preferred drilling procedure for installing wells is the hollow-stem auger method. However, site conditions may not always be amenable to using the hollow-stem auger method. When this occurs, an alternate method shall be selected that will perform acceptably under the encountered site conditions. It is advisable to select several alternate methods and be prepared to use them if a field problem suddenly occurs that warrants a drilling change. This discussion is presented so that SOPs will be employed by all NRT staff and contractors who are associated with the design, drilling, and installation of permanent monitoring wells.

The following drilling methods are listed in order of preference; however, final selection shall be based on actual site conditions. Reference SOP 07-05-02 for drilling method specific procedures.

- Hollow-Stem Auger;
- Solid-Stem Auger;
- Hydraulic Push;
- Sonic Rotary;
- Water Rotary;
- Direct Wireline Rotary;
- Air Rotary;
- Dual-Wall Reverse Circulation Air Rotary;
- Mud Rotary;
- Cable-Tool (not recommended);
- Jetting Method (not recommended); and,
- Bucket Auger (not recommended).

A senior staff geologist or engineer shall approve the use of non-recommended methods before fieldwork is initiated.

1.5 Borehole Requirements

1.5.1 Borehole Diameter

The borehole shall be of sufficient diameter so that well construction can proceed without major difficulties. For example, Wisconsin regulations require borehole diameter to be at least 4 inches greater than the well casing (an 8-inch borehole is required to install a 4-inch outside diameter (OD) casing). However, if the inside diameter (ID) of the casing is 4 inches, the OD of the casing is nearly 4.5 inches and the borehole will have to be larger than 8 inches to meet current regulations. This allows an annular space around the well casing large enough to install the required filter pack, bentonite pellet seal, and the annular grout to the acceptable thicknesses. In addition, this annular space will allow up to a 1.5-inch diameter tremie tube for placing the filter pack, pellet seal, and grout at the specified intervals. A borehole diameter less than 4 inches larger than the well casing will not be acceptable. When installing a well inside of hollow stem augers, the ID of the augers is the area to be considered when determining the 2-inch annular space.

1.5.2 Overdrilling the Borehole

Sometimes it is necessary to overdrill the borehole so any soils that have not been removed or have fallen into the borehole during auger or drill stem retrieval, will fall to the bottom of the borehole below the depth where the filter pack and well screen are to be placed. Normally, several feet are sufficient for overdrilling. If the borehole is overdrilled it can be backfilled to the designed depth with bentonite pellets or the filter sand that is to be used for the filter pack. However, use of bentonite requires care so that bentonite does not clog the well screen after it swells. A Senior Geologist should be consulted before using bentonite.

1.5.3 Filter Pack Placement

When placing the filter pack into the borehole, a minimum of 6 inches of the filter pack material shall be placed under the bottom of the well screen to provide a firm footing and an unrestricted flow under the screened area. In addition, the filter pack shall extend a minimum of two feet above the top of the well screen. The filter pack shall be placed by the tremie or positive displacement method. Placing the filter pack by "pouring" may be acceptable in certain situations; however, this will be discussed in the next section.

1.5.4 Filter Pack Seal

A seal shall be placed on top of the filter pack. This seal shall consist of a high solids, pure bentonite material. The solids content shall be at least 20 percent. Bentonite materials that have a solids content of 20 percent or greater are available in powder form or in the form of pellets compressed to a density of 70 to 80 lbs/cu.ft. The preferred method of placing bentonite pellets is by the positive displacement or the tremie method. Use of the tremie method minimizes the risk of pellets bridging in the borehole and assures the placement of pellets (also sand and grout) at the proper intervals. Pouring of the pellets (and filter pack materials) is acceptable in shallow boreholes (less than 50 feet) where the annular space is large enough to prevent bridging and to allow measuring (with a tape measure) to insure that the pellets have been placed at the proper intervals. In order to insure that the pellets have been placed at the proper intervals, the pellets shall be tamped, with an appropriate tamping tool, while the measuring is being conducted. The tamping process minimizes the potential for pellet bridging by forcing any pellets that have lodged against the borehole wall and/or the well casing, down to the proper interval. The bentonite seal shall be placed above the filter pack at a minimum of two feet vertical thickness. The hydration time for the bentonite pellets shall be a minimum eight hours or the manufacturer's recommended hydration time, whichever is greater. In all cases, the proper depths shall be documented by measuring and not by estimating. Other forms of bentonite such as granular bentonite or bentonite chips have limited applications, and are not recommended for the bentonite seal unless special conditions warrant their use. A senior staff geologist should approve any deviation from bentonite pellets for the seal. If for some reason, the water table is temporarily below the pellet seal interval, potable water (or a higher quality water) shall be used to hydrate the pellets.

1.5.5 Annular Space Seal

The annular space between the casing and the borehole wall shall be filled with either a high solids, pure (no additives), bentonite grout, a neat cement grout, or a cement/bentonite grout. Each type of grout to be used shall be evaluated as to its intended use and integrity. The grout shall be placed into the borehole, by the tremie method, from the top of the bentonite seal to within 2 feet of the ground surface or below the frost line, whichever is greater. The tremie tube shall have a side discharge port or a bottom discharge port, to minimize damage to the filter pack and/or the bentonite pellet seal, during grout placement. The grout shall be allowed to "set" or cure for a minimum of 24 hours before the concrete surface pad is installed. All grouts shall be prepared in accordance with the manufacturer's specifications. Bentonite grouts shall have a minimum density of 9.4 pounds per gallon (lbs/gal) to ensure proper set-up. The density of the bentonite grouts shall be measured while mixing and no pumping of grout into the borehole will be allowed until the minimum density of 9.4 lbs/gal is attained. In addition, the grouting operation shall not cease until the grout flowing out of the borehole has a minimum density of 9.4 lbs/gal. A mud balance shall be used to measure the specified grout density. Estimating the grout density shall not be acceptable. Drilling mud will not be acceptable for grouting.

Cement grouts shall be mixed using 6.5 to 7 gallons of water per 94-lb bag of Portland cement (Type I). The addition of bentonite (5 to 10 percent) to the cement grout is for elasticity and the reason for its use shall be documented. The specific mixtures and other types of cements and/or grouts shall be evaluated on a case-by-case basis.

1.5.6 Well Casing and Protective Cover

1.5.6.1 Above Ground

The well casing, when installed and grouted, shall extend above the ground surface a minimum of 2.5 feet. In high traffic areas, the well casing may be located below grade, with a waterproof cover. A vent hole shall be drilled or cut into the top of the well casing cap to permit pressure equalization, if applicable. An outer protective casing shall be installed into the borehole after the annular grout has "set" for at least 24 hours. The outer protective casing shall be of steel construction with a hinged or slip-on, locking cap. Generally, an outer protective casing used over a 2-inch well casing is 4 inches square by 5 feet long. Similarly, a protective casing used over 4-inch well casings is 6 inches square and 5 feet long. Round protective casings are also acceptable. A protective casing shall have sufficient clearance around the inner well casing, so that the outer protective casing will not come into contact with the inner well casing after installation. The protective casing shall have a minimum of two weep holes for drainage. These weep holes shall be a minimum ¼ inch in diameter and drilled into the protective casing just above the top of the level of concrete inside the protective casing to prevent water from standing inside of the protective casing. A protective casing made of aluminum or other soft metals is not acceptable because it is not strong enough to resist tampering. The protective casing is installed by pouring concrete into the borehole on top of the grout. The protective casing is then pushed into the wet concrete and borehole a minimum of 2 feet. Extra concrete may be needed to fill the inside of the protective casing so that the level of the concrete inside of the protective casing is at or above the level of the surface pad. The protective casings shall extend a minimum of 3 feet above the ground surface or to a height so that the cap of the inner well casing is exposed when the protective casing is opened.

1.5.6.2 Additional Surface Protection

If the monitoring wells are located in a high traffic area, a minimum of three bumper guards should be installed. Bumper posts should be steel pipes 3 to 4 inches in diameter and a minimum 5-foot length, and should be installed to a minimum depth of 2 feet below ground surface (bgs) in a concrete footing and extend a minimum of 3 feet above ground surface. Concrete shall also be placed into the steel pipe to provide additional strength. Steel rails and/or other steel materials can be used in place of steel pipe but approval must be granted by a senior staff geologist or engineer prior to field installation.

1.5.7 Surface Seal

A concrete surface pad may be installed around each well at the same time as the outer protective casing is being installed. The surface pad shall be formed around the well casing. Concrete shall be placed into the formed pad and into the borehole (on top of the grout) in one operation making a contiguous unit. The protective casing is then installed into the concrete as described in the previous section. The size of the concrete surface pad is dependent on the well casing size. If the well casing is two inches in diameter, the pad shall be 3 feet by 3 feet by 6 inches. If the well casing is 4 inches in diameter, the pad shall be 4 feet by 4 feet by 6 inches. Round concrete surface pads are also acceptable. The finished pad shall be sloped so that drainage will flow away from the protective casing and off of the pad. In addition, a minimum of one inch of the finished pad shall be bgs or ground elevation to prevent washing and undermining by soil erosion. At each site, all locks on the outer protective casings shall be keyed alike.

1.6 Construction Methods

1.6.1 Well Installation

First, an appropriate drilling method shall be chosen, given the site logistics, aquifer properties and desired dimensions of the well. Then the depth and volume of the borehole, including over drilling if applicable, shall be calculated and the appropriate materials procured prior to drilling (this is generally done by the drilling subcontractor). Finally, the borehole shall be advanced as close to vertical as possible, and checked with a plumb bob or level. Slanted boreholes are not acceptable unless specified in the design.

Following borehole completion, the well string is constructed by securing the PVC riser to the well screen by flush-jointed threads. Lubricating oils and grease shall not be used on casing threads. Teflon tape can be used to wrap the threads to insure a tight fit and minimize leakage. No glue of any type shall be used to secure casing joints. Teflon® "O" rings can also be used to insure a tight fit and minimize leakage;

however, "O" rings made of other materials are not acceptable if the well is going to be sampled for organic compounds.

Before the well string is lowered into the borehole, six to 12 inches of clean filter pack sand shall be placed at the bottom of the borehole. Then the well string shall be placed into the borehole through the hollow-stem auger or temporary casing and plumbed. Centralizers can be used to plumb a well, but may interfere with the placement of the filter pack, bentonite pellet seal, and annular space seal. Centralizers placed in the wrong locations can cause bridging during material placement. Monitoring wells less than 50 feet deep generally do not need centralizers. If centralizers are used they should be placed below the well screen and above the bentonite pellet seal. The specific placement intervals shall be decided based on-site conditions.

When installing the well string through hollow-stem augers, the augers shall be slowly extracted as the sand pack, bentonite seal (if necessary) and annular space seal are tremied and/or poured into place. The extraction of the augers allows the materials being placed through the augers to flow below the augers, rather than up into the augers causing the augers to become stuck in the borehole.

After the well string is plumb, the filter material shall be poured or tremie-piped around the well screen up to the designated depth (generally six inches to two feet above the well screen). After the filter pack has been installed, six inches to two feet of fine sand shall be placed on top of the filter pack as a filter pack seal. Next, the bentonite seal, consisting of 3/8” bentonite chips, bentonite pellets or bentonite granules, depending on site conditions, shall be placed, if necessary. The bentonite seal extends from the top of the filter pack seal to the bottom of the annular space seal, generally two to five feet above the filter pack seal. The annular space seal, consisting of bentonite granules, chips, grout or slurry, depending on site conditions, shall then be pumped by the tremie method or poured into the annular space around the PVC casing up to one foot bgs for a flush-mounted protective cover or two inches bgs for a stick-up protective cover. Bentonite may not be placed between the well casing and protective cover pipe; sand or native soil must be used to allow water to drain away from the well. If grout is used, it shall be allowed to set for a minimum of 24 hours before the surface seal and protective cover pipe are installed.

Following placement of the annular space seal, the protective cover pipe is installed. A stick-up protective cover pipe shall extend above the top of the PVC casing so that a slipcover may be secured over the casing, and the protective cover shall have a lockable cap. The stick-up protective cover shall extend at least two feet bgs, and not extend below the annular space seal into the filter pack. Two inches of topsoil or native soil shall be placed on top of the bentonite annular space seal/ surface seal to prevent drying and cracking, individual states may have greater requirements[1].

A flush-mounted protective cover pipe shall extend at least one foot bgs, be made of steel, aluminum, iron, or some such material to withstand traffic, and have a watertight seal. The PVC well casing shall be cut off low enough so that a lockable Labcock cover may be secured over the casing. The Labcock cover must be locked to prevent tampering with or filling of the well. Concrete surface seals must be installed around a flush-mounted protective cover, and extend to the bottom of the protective cover pipe. The flush-mounted cover shall be installed slightly (1/2 to 1 inch) above the surrounding ground surface and the concrete pad installed sloping away from the cover to facilitate drainage away from the well and reduce ponding of water over the well.

After the surface pad and protective casing are installed, bumper guards may be installed (if needed). The bumper guards shall be placed around or incorporated into the concrete surface pad in a configuration that provides maximum protection to the well. Each piece of steel pipe or approved material shall be installed into an 8- to 10-inch diameter hole to a minimum depth of 2 feet bgs and filled with concrete. The bumper guard shall extend above the ground surface a minimum of 3 feet, and have a minimum length of 5 feet.

After the wells have been installed, they shall be permanently marked with the well number on either the cover or an appropriate place that will not be easily damaged and/or vandalized.

1.6.2 Cased Wells

Double cased wells shall be constructed when there is reason to believe that interconnection of two aquifers by well construction may cause cross-contamination, when flowing sands make it impossible to install a monitoring well using conventional methods, and/or in special casing areas designated by the WDNR or other such agency. A pilot borehole shall be bored through the overburden and/or the contaminated zone into the clay confining layer or bedrock. An outer casing (sometimes called surface or

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[1] NOTE: In the state of Wisconsin, monitoring wells must be constructed with a minimum of 1 foot of surface seal and 2 feet of annular space seal.

pilot casing) shall then be placed into the borehole and sealed with grout. The borehole and outer casing shall extend into tight clay a minimum of five feet and into competent bedrock a minimum of two feet. The total depths into the clay or bedrock will vary, depending on the plasticity of the clay and the extent of weathering and/or fracturing of the bedrock.

The size of the outer casing shall be of sufficient ID to contain the inner casing and the 2-inch minimum annular space. Additionally, the borehole shall be of sufficient size to contain the outer casing and the 2-inch minimum outer annular space. The outer casing shall be grouted by the tremie method or pressure grouting to within 2 feet of the ground surface. The grout shall be pumped into the annular space between the outer casing and the borehole wall by placing the tremie tube in the annular space and pumping the grout from the bottom of the borehole to the surface, or placing a grout shoe or plug inside the casing at the bottom of the borehole and pumping the grout through the bottom grout plug and up the annular space on the outside of the casing. If the outer casing is set into very tight clay, both of the above methods might have to be used, because the clay usually forms a tight seal in the bottom and around the outside of the casing preventing grout from flowing freely during injection. Conversely, outer casing set into bedrock normally will have space enough to allow grout to flow freely during injection.

The grout mixture used to seal the outer annular space can be neat cement, cement/bentonite, cement/sand, or a pure bentonite grout. However, the seal or plug at the bottom of the borehole and outer casing shall consist of a Type I Portland cement/bentonite or cement/sand mixture. The use of a pure bentonite grout for a bottom plug is not acceptable as the bentonite grout cures to a gel and is not rigid enough to withstand the stresses of drilling. A minimum of 24 hours shall be allowed for the grout plug to cure before attempting to drill through it.

When drilling through the seal, care shall be taken to avoid cracking, shattering, and/or washing out the seal, discussed below. Removal of outer casings, which are sometimes called temporary surface casings, after well screens and casings have been installed and grouted is not acceptable. Trying to remove outer surface casings after the inner casings have been grouted may jeopardize the structural integrity of the well.

1.6.3 Bedrock Wells

The installation of monitoring wells into bedrock can be accomplished in three ways:

1. The first method is to drill or bore a pilot borehole through the soil overburden into the bedrock. An outer casing is then installed into the borehole by setting it into the bedrock, and grouting it into place as described in the previous section. After the grout has set, the borehole can then be advanced through the grout seal into the bedrock.

   The preferred method of advancing the borehole into the bedrock is rock coring. Rock coring makes a smooth, round hole through the seal and into the bedrock without cracking and/or shattering the seal. Roller cone bits are used in soft bedrock, but extreme caution shall be taken when using a roller cone bit to advance through the grout seal in the bottom of the borehole because excessive water and "down" pressure can cause cracking, eroding(washing), and/or shattering of the seal. Low volume air hammers have been used to advance the borehole, but they have a tendency to shatter the seal because of the hammering action. Any proposed method will be evaluated on its own merits, and will have to be approved by a senior staff geologist before drilling activities begin.

   When the drilling is complete, the finished well consists of an open borehole from the ground surface to the bottom of the well. There is no inner casing, and the outer surface casing, installed down into bedrock, extends above the ground surface, and also serves as the outer protective casing. If the protective casing becomes cracked or sheared off at the ground surface, the well is open to direct contamination from the ground surface and will have to be repaired immediately or abandoned. In some instances, the outer surface casing is cut off at the surface or bgs, depending on the design, and a separate outer protective casing is installed. Another limitation to the open rock well is that the entire bedrock interval serves as the monitoring zone. In this situation, it is very difficult or even impossible to monitor a specific zone, because the contaminants being monitored could be diluted to the extent of being non-detectable. The use of open bedrock wells is generally not acceptable in the Superfund and RCRA programs because of the uncontrolled monitoring intervals. However, some site conditions might exist, especially in cavernous limestone areas (Karst topography) or in areas of highly fractured bedrock, where the installation of the filter pack and its structural integrity are questionable. Under these conditions, the design of an open bedrock well may be warranted.

2. The second method of installing a monitoring well into bedrock is to install the outer surface casing and drill the borehole (by the approved method) into bedrock, and then install an inner casing and well screen with the filter pack, bentonite seal, and annular grout. The well is completed with a surface protective casing and concrete pad. This well installation method gives the flexibility of isolating the monitoring zone(s) and minimizing inter-aquifer flow. In addition, it gives structural integrity to the well, especially in unstable areas (steeply dipping shale, etc.) where the bedrock has a tendency to shift or move when disturbed. Omitting the filter pack around the well screen is a general practice in some open rock borehole installations, especially in drinking water and irrigation wells. However, without the filter pack to protect the screened interval, sediment particles from the well installation and/or from the monitoring zone could clog the well screen and/or fill the screened portion of the well rendering it inoperable. In addition, the filter pack serves as a barrier between the bentonite seal and the screened interval. Rubber inflatable packers have been used to place the bentonite seal when the filter pack is omitted. This method is not acceptable because the packers have to remain in the well permanently and, over a period of time, will decompose and possibly contribute contaminants to the monitoring zone.

3. Finally, sonic rotary drilling may be used to advance temporary casing directly into the bedrock and a conventional well may be constructed within the casing. The temporary casing may then be removed and grout is not necessary, other than for the annular space seal.

1.7 Well Development

Completed monitoring wells can be developed immediately unless constructed and sealed with a "liquid" grout seal. Wells constructed with grout seals, (and all other wells, if possible), should not be developed for at least 12 hours after they are installed. This allows sufficient time for the well materials to "set" and cure before development procedures are initiated. The main purpose of developing new wells is to remove the residual materials remaining in the wells after installation has been completed, and to try to re-establish the natural hydraulic flow conditions of the formation, disturbed by well construction, around the immediate vicinity of the well. New wells shall be developed until the column of water in the well is free of visible sediment, and the pH, temperature, and specific conductivity have stabilized.

In most cases the above requirements can be satisfied; however, in some cases the pH, temperature, and specific conductivity stabilizes but the water remains turbid. In this case the well may still contain well construction materials, such as drilling mud in the form of a mud cake and/or formation soils that have not been washed out of the borehole. Excessive or thick drilling mud cannot be flushed out of a borehole with one or two well volumes of purge water. Continuous flushing for several days may be necessary to complete the well development. If the well is pumped to dry (or nearly dry), the water table shall be allowed to recover sufficiently before the development continues. Caution should be taken when using high rate pumps and/or large volume air compressors during well development because excessive high rate pumping and high air pressures can damage or destroy the well screen and filter pack. The on-site geologist shall make the decision as to the development completion of each well. All field decisions shall be documented in the field logbook.

The following development procedures are generally used to develop monitoring wells:

- Pumping;
- Compressed air (with the appropriate organic filter system);
- Bailing;
- Surging;

- Backwashing ("rawhiding"); and
- Jetting.

The previous methods can be used, both individually and in combination, in order to achieve the most effective well development. The selected development method(s) shall be approved by a senior staff geologist before any well installation activities are initiated.

1.8 References

ASTM International, ASTM D5092-04 Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers

ASTM International, D6001-05 Guide for Direct-Push Ground Water Sampling for Environmental Site Characterization

ASTM International, D6724-04 Guide for Installation of Direct Push Ground Water Monitoring Wells

ASTM International, D6725-04 Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers

USEPA, 2002, Ecological Assessment Standard Operating Procedures and Quality Assurance Manual, SESD, Region 4, Ecological Assessment Branch, Athens, Georgia.

GROUNDWATER SAMPLING

1.1 Scope and Application

This standard contains detailed procedures for sampling groundwater. Following these procedures will provide samples that are as representative as possible, the subsequent analysis of which will provide analytical data that is of high quality and fully defensible. This standard is not only intended to be used in training personnel involved in sampling, but as a reference to the proper procedures to be followed even by experienced samplers.

The objective of a groundwater-monitoring program is to determine to what extent contaminants from a site are impacting the groundwater. Federal, state, and local regulatory bodies have established criteria that must be met for clean up standards.

This standard provides the procedures necessary to carry out the first and most critical element in a groundwater-monitoring program--the sampling. Other elements of a groundwater-monitoring program can be found in the site specific Work Plan, or Quality Assurance Project Plan (QAPP), whichever is applicable.

Field books will be used to record and document each sampling event. Field forms are available for use, but use of the field book is recommended to keep all pertinent data together concerning each specific job. If field forms are used, it is necessary that copies of all forms be maintained in the project files.

1.2 Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety (H&S) standard operating procedures (SOPs) when working with potentially hazardous material or with material of unknown origin,. Project-specific H&S plans will contain additional practices, if necessary, that are necessary to mitigate project- or site-specific hazards.

1.3 Preliminary Procedures

Prior to any sampling at a site, a number of preliminary tasks must be accomplished. These preliminary procedures may be done infrequently; but if done properly the first time, can insure that the subsequent sampling events are carried out smoothly and cost effectively.

1.3.1 Coordination with Analytical Laboratory

For a scheduled sampling event, the analytical laboratory should be notified a minimum of one week prior to sampling. Sample bottles and shuttles are typically sent via courier for delivery. For rapid response projects, designated by the Project Manager, shuttles and bottles can be sent express (overnight) or delivered by the lab. To minimize the need for express shipments, a limited amount of sample bottles and supplies may be stored at local labs, or at the site if storage space is available. However, short notice of a project tends to increase project costs. As much notice as possible should be given on any project. The information described in the following paragraphs is to be defined with the laboratory or other supplier in placing an order for sample bottles.

1.3.2 Number of Samples and Matrix

The number of samples to be collected and analyzed including field and trip blanks, sample types and matrices (e.g., water, soil, etc.) are to be defined. It is important to identify samples which may have a complex matrix or potential interferences, such as high sulfide or chloride concentrations. These samples may require special cleanup procedures prior to analysis. The number, size, and type of sample bottles required should be determined in conjunction with the analytical laboratory prior to ordering sample bottles and preservatives.

1.3.3 Sample Point IDs

Sample point designations must be standardized to avoid confusion. Sample point designations are to be alphanumeric characters. For samples which are field duplicates, the appropriate source code with the ID code is to be used. Whenever necessary, standard USEPA protocol for identifying samples will be followed so that data collected for NPL or CERCLA sites is correctly labeled.

1.3.4 Sampling Date(s)/Schedule

Specific dates for sample collection are to be scheduled as soon as possible. Anticipated dates for sample arrival at the laboratory(s) will be identified so the laboratory manager may schedule work and reserve laboratory capacity for the project.

1.3.5 Turnaround

Standard turnaround times for analytical results should be within 28 days from receipt of sample by the laboratory. Exception to this may be required for unusual detection limits, odd matrices, or special compounds. Express or emergency turnaround, when required, must be identified.

1.3.6 Parameters to be Analyzed/Reporting Requirements

The parameters to be analyzed are to be listed by sample on the Chain-of-Custody (COC) in accordance with SOP 07-03-02. If required, special detection limits or methodologies required must be defined under special instructions. In all cases, the COC will identify the specific USEPA approved method of analysis to be performed on each sample.

1.3.7 Special Comments

Special instructions must also be noted. For example:

- Special packing requirements should be noted (e.g., bottles required for splits);
- Special report requirements (e.g., state reporting forms, distribution of results to interested parties);
- Known interferences or known high levels of a compound from a specified sample point should be identified so that special analytical procedures can be undertaken. For example, petroleum hydrocarbon samples should identify, if known, the type of hydrocarbon present (e.g., gasoline, fuel oil #2 etc); and
- Sample filtering procedures which are to be used in the field should be noted on field forms and/or field notes.

1.4 PRE-SAMPLING PROCEDURES

Once the wells have been located and the order placed, preplanning must be done to reduce the chance of errors and/or delays. These pre-sampling procedures include the procurement and calibration of equipment, checking sample shuttle, filling out field form, and purging the well. Each of these procedures is addressed in the following paragraphs. It is suggested that preparation for a sample event begin at least one day before the event is to take place to ensure time to accomplish all of the procedures and to leave time to address and/or correct any problems that arise.

1.4.1 Organizing Equipment and Materials

All equipment necessary for a sampling event should be cleaned, checked, and, if necessary, calibrated prior to going into the field. As much preparation as possible should be done ahead of time since neither the facilities nor the material required for equipment cleaning and calibration may be available at the site.

The following is a checklist of equipment that may be required for a sampling event. Additional supplies may be needed but this is a starting point for preparing and assembling the required equipment for a sampling event.

<u>Sampling Checklist</u>

- Sampling Scope and Site Map(s)
- Field Log Book and/or Field Forms
- Well and Site Access Keys
- Well repair items (e.g., locks, bolts, etc.)
- Mobile Phone
- Tools/Tool Chest including tape measure
- Camera
- Calculator / Conversion Chart
- Applicable Regulations
- Extension Cords
- Disposable / Dedicated Bailers
- Submersible Pump
- Water Level and Interface Probes
- Water Quality Probe
- Generator with gasoline and oil
- Transfer, Peristaltic, and/or bladder Pumps
- Water Filters and associated supplies
- Plastic Sample Bags and Paper Towels
- COC Forms and seals
- Coolers and ice
- Strapping Tape
- Pens/Markers
- Sample Bottles and Labels
- Gloves (vinyl, neoprene, and work)
- 5 Gallon Buckets (site dependent)
- Alconox Soap
- Brushes (large and small)
- Bristle Pad (Scrubby)
- DI Spray Bottle (spritzer)
- Site-specific Decontamination Liquids (e.g., methanol)
- Gloves (vinyl, neoprene, and work)

Reusable Safety Supply Checklist:

- Coveralls
- Steel-toe Boots (Leather & Neoprene)
- Hard hat
- Safety Glasses w/side shields
- First Aid Kit
- Tyvek Coveralls
- Respirator & Cartridges

1.5 Equipment Storage

After all shuttles, containers, and equipment are checked or packed, they must be stored prior to the sampling event in a designated, contaminant free area. On occasion, not all bottles and containers will be used (e.g., the well was dry and no sample was obtained). Unused shuttles and/or bottles should be returned to the laboratory of origin, if applicable, at the completion of the sampling event. The laboratory must be notified regarding the return of unused shuttles.

1.6 Calibration and Use of Meters

Field measurements along with proper documentation are integral parts of the monitoring program. Before the actual trip to the field, all equipment must be checked for possible malfunctions and cleaned in accordance with SOPs 07-11-01 and 07-11-02.

1.7 Shuttles and Sample Bottles

The sampler will be responsible for checking all sample bottles and shuttles as soon as they are received. They are to notify the laboratory immediately as to any problems or questions. The COC should be included with the sample shuttle and must be filled out and returned with the samples in accordance with SOP 07-03-02. If sample bottles are received in a shuttle, note the arrangement of the bottles within prior to removing equipment from the shuttle in order to re-pack them. Shuttles are packed for economy of space and often, unless special attention is given, it may be difficult to fit everything back into them.

An inventory of the bottles and their condition must be taken. A bottle list as well as analyses required and preservation requirements are noted on the COC in the "Sample Bottle" section. Each sample bottle is to be labeled with the NRT project number.

1.8 Field Records

Improper documentation or inadequate information regarding the circumstances of collection and/or subsequent disposition of the samples (e.g., COC) may render any resulting data useless. Proper COC documentation is crucial as part of the QA/QC program. Comprehensive, consistent, and accurate documentation of field tests, measurements, and field observations is also extremely important. This information should be recorded in field notebooks and/or field forms as a permanent record of the work performed. Copies of completed forms and/or field notes will be maintained in the master project file.

Field activities will be documented in accordance with SOP 07-02-01 and will include at minimum:

- Weather condition--wind direction and speed, upwind activities, rain, snow, temperature, cloud cover, barometric pressure (where required per regulatory requirements), etc;
- Owner’s and occupant’s name(s);
- Facility name and address;
- Site and well specific identification information;
- Condition of the well and dedicated equipment;
- Reference point for well measurements;
- Well ID where field blank is prepared.
- All calculations for purge volumes and temperature conversions, as well as if well was purged dry, or an explanation when less than 4 casing volumes are removed .
- Duplicate field measurement results.
- Purge flow rate;
- Purge time;
- Total purge volume;
- Sample appearance (odor, color, turbidity, etc.);
  - Odor: Rotten eggs, earthy, strong, moderate, slight, metallic;
  - Color: True "color" is the color after the turbidity has been removed. The color observed after sampling is an "apparent color”, influenced by sediment in the sample.

True color may be caused by metallic ions, humus, peat, industrial chemicals. Hold the sample up to the light and describe the color as well as possible. Observations may include: no color (clear), brown, gray, yellow etc.;

– Turbidity:
None - sample is clear
Trace - Sediment only slightly clouds or colors the sample. Sediment does not accumulate at bottom of bottle.
Moderate - Definite cloudiness/color. Sediment accumulates at bottom of sample bottle.
High - muddy appearance.

- Other conditions, such as sample splits with regulatory agencies, potential safety, or health hazards (e.g., fire ants, dry well, etc.). When samples are split with regulatory agencies, note the condition of the bottles, preservatives used, etc., by the agency on the summary sheet.

- NOTE: When samples are split with regulatory agencies, note the condition of the bottles, preservatives used, etc., by the agency on the summary sheet.

1.9 Conditions That Dictate the Samples Should Not Be Collected

During a sampling event, wells scheduled for sampling must be sampled, except in the following cases:

- Well has been destroyed or otherwise rendered useless (e.g., casing broken off or severely bent so as to preclude sampling);

- Well is dry (i.e., no water can be pumped within 24 hours of purging, or bailed without dropping the bailer all the way to the silt at the bottom of the well to obtain a partial bailer full of water, unless regulatory requirements dictate awaiting a longer recharge time or as specified by the Project Manager);

- Well is new and has not been properly developed (pH and specific conductivity must be stabilized); or

- The Project Manager states that the sampling should not be done.

1.10 Sample Preservation, Storage, and Shipment

Sample preservation, storage, and shipment will be conducted in accordance with SOP 07-03-01. ALL BOTTLES, CORRESPONDING COC, AND FIELD PARAMETER FORMS MUST HAVE THE SAME SAMPLE POINT ID NUMBER AND NRT PROJECT NUMBER. All bottles filled from the same sample point at the same time must have identical sample codes and sample numbers unless used for duplicate analysis, in which case a different number will be used. Bottle tags should be double-checked for consistency. Samples which are split with regulatory agencies should also be checked for consistent sample point ID numbers and for other methods of identification if used by the agency.

1.11 Re-sampling

Re-sampling of wells between regularly scheduled sampling events should be kept to a minimum. The decision to resample, based on the analytical results, should always be reviewed with the Project Manager. However, in cases where sample are received broken, samples are missing, etc., these wells should generally be re-sampled as soon as possible.

1.12 Sampling Procedures other than Low-Flow Techniques

1.12.1 Bailers

Dedicated PVC bailers are preferable when monitoring for organics, and are appropriate for sampling all required RCRA parameters. Teflon or stainless steel bailers are the second choice. Non-dedicated bailers must be washed with a phosphate-free detergent and triple-rinsed with DI water between wells. Dedicated bailers require no rinsing unless they are visibly contaminated by LNAPLs, in which case they should be completely decontaminated before use. Disposable PVC bailers can also be used at locations where one-time samples will be collected. Use of these bailers will facilitate sampling by allowing more time to be spent on sampling rather than on decontamination of the sampling equipment.

1.12.2 Pumps

The selection of pumps should be geared to the nature of the parameters. There are several advantages and disadvantages to each type of pump. Use of suction lift pumps may result in degassing and loss of volatile components. Portable submersible pumps are not suitable when sampling for organics if lubricants are used in the pump. Gas stripping of volatile compounds may occur with airlift samplers and are generally not suited for pH sensitive parameters such as metals. Well Wizards or similar brands (air actuated, peristaltic pumps, constructed of PVC, stainless steel, or Teflon), therefore, are the preferable equipment when pumps are needed.

When non-dedicated pumps are used, stringent cleaning procedures must be followed between both the separate site wells and individual sites. Before purging wells at the next site, sufficient amounts of DI water must be flushed through the pump and tubing.

The cleaning procedures should be performed in a clean room/laboratory environment. The non-dedicated pump should be placed in a standpipe (PVC or stainless steel) filled with DI water. (NOTE: A continual supply of DI water must be added to the standpipe.)

Initial specific conductance and amount of DI water used should be accurately measured and recorded in the field notebook. Pump and tubing should continue to be flushed until the specific conductance of the discharged DI water is within ±10 (µm/cm at 25°C) of the initial measurement. Once this is achieved, the pumps and tubing should be properly stored and will be ready for use at the next site.

Decontamination procedures at the sample locations are equally important. To ensure the integrity of the non-dedicated pump between wells, a minimum of 3-gallons of DI water should be used to thoroughly flush the pump and tubing before and after use in the well.

1.12.3 Well Purging

Monitoring wells should be pumped or bailed prior to sample withdrawal to safeguard against collecting non-representative stagnant water in a sample. Generally, a minimum of three times the well volume of water standing in the well casing will be removed prior to sampling the well, or as specified in site-specific work plans. Well purging should be sufficient to ensure that water which is representative of the groundwater has entered the well.

If a monitoring well is a very low yield well, bail the volume of water standing in the well and allow the well to recharge for 24 hours. If there is insufficient water for sampling any parameter, then the well is considered dry for the sampling event. If the volume of water available is insufficient for filling all of the sample containers, portions of the sample are to be collected (unless otherwise specified by the regulatory agency or the Project Manager). In all of these situations, notify the Project Manager immediately.

In special situations, such as very tight clay till, wells may be allowed to recharge for a longer period, or as otherwise specified by the Site Specific Sampling Plan.

1.12.3.1 Calculating Purge Volume

The following equation can be used to determine the volume of water to be purged.

- h = height of water column (feet) = total well depth (feet) - depth to water (feet)
- • Casing Volume = πr2h = π (1/2 well ID)2h*
- • Purge volume = 4 casing volumes

Note: Purge volume calculation must be made in equivalent units, so if feet of water is used for h, well diameter must be converted to feet (i.e., 2" ID well = 1" radius = 0.083' radius; therefore r2 for 2" ID well = 0.0069', and for each 1-foot of water in a well π^{r}2(1) = 0.022 ft3 (7.48 gal/ft3) = 0.16 gal).

After necessary field measurements are made and the volume of water to be purged is determined, the purging process is begun.

The single most important objective while purging a well is minimizing contamination. Equipment should never touch the ground or any other possible contamination sources. For example, a bucket or drum lined with a new plastic bag may be used to collect the rope in when using a bailer. Purged water should be discarded away from the well footing or in the manner described in the site-specific work plan. This will prevent the possibility of contamination due to the formation of mud.

To measure the volume of water being removed from the well, a calibrated 5-gallon bucket or a known volume container may be used to collect water.

1.12.3.2 Bailers

When using a bailer for purging, the largest available bailer that will fit into the well should be used in order to minimize purge time.

Nylon rope, preferably braided, is to be used. It is imperative that new rope be utilized. In addition, the rope should be of adequate length and strength--thicker rope is easier to grip. The rope should be fastened to the protective casing or some other object which will prevent the loss of the rope and bailer down the well.

If a non-dedicated bailer is used, the bailer must be washed with a non-phosphate detergent and triple rinsed inside and out with DI water before purging. Additionally, the people handling the bailer should wash their hands before purging the well. Disposable PVC or latex powderless gloves must be worn (the powder contains phthalates which can contaminate samples). New gloves should be used at each well or possibly changed more frequently (e.g., dirty, torn, etc.). The rope should be tied onto the bailer securely and checked with each bail during the purging process.

The purging of the well is accomplished by a repetitive lowering, raising, and dumping of the bailer.

1. Slowly lower the bailer into the well until the bailer contacts the water.
2. Allow the bailer to fill with water. The bailer will "gulp" when it is full and increased tension will be felt on the rope.
3. Pull the bailer out of the well while coiling the rope and dropping it in the plastic bag lined fiber drum.
4. Pour out the water from the bailer, into a calibrated bucket, and observe water characteristics.
5. Repeat the process until the appropriate volume of water has been purged from the well.

<u>Suggested precautions while purging a well</u>:

1. Lower the bailer slowly into the well;
    a. To prevent contamination from rust or the sediment that may accumulate around the top of the well casing.
    b. To minimize the upwelling of bottom sediment.
    c. To minimize the possibility of the bailer becoming lodged in the well due to a kink in the well casing.
    d. To minimize the chance of the rope becoming untied from the bailer.
2. Never allow the bailer to come in contact with any surface other than your gloves and the inside of the well.
3. Always be conscious of possible contamination sources (i.e., grease on well cap, etc.) and remove these sources to the extent practical.

1.12.3.3 Pumps - Non-Dedicated

Non-dedicated pumps are most often used for purging when large volumes of water must be removed from the well prior to sampling. The best, and most commonly used pumps are submersible, centrifugal pumps.

All of the equipment must be thoroughly washed using a non-phosphate detergent and rinsed with tap water followed by a DI water rinse and air dried before using. Refer to SOP 07-04-05 for a more detailed discussion of decontamination requirements.

The samplers should wash their hands before purging the well. Disposable PVC or latex powderless gloves must be worn. New gloves should be used at each well or possibly changed more frequently (e.g., dirty, torn, etc.).

Purging of the well basically involves the correct placement of the pump and turning it on.

1. Slowly lower the equipment (pump, hose, rope) into the well. All of the equipment must be lowered simultaneously to prevent possible jamming of the equipment in the well.
2. Place the pump as far as possible below the static water level head, (above the well screen in piezometers) as damage to the pump may occur if the pump is run dry for even a few seconds.
3. Turn on the pump - Purge the required volume of water - Turn pump off.
4. Remove equipment from the well when purging is complete. All equipment must be removed simultaneously to prevent possible jamming of the equipment in the well.
5. Decontaminate all equipment before reusing, per the procedure for cleaning discussed above.

1.12.3.4 Pump - Dedicated

Dedicated pumps involve the connection of the dedicated pump to its power source and turning it on. Electrical power sources (where possible) are preferred in order to minimize possible contamination sources.

1.12.4 Well Sampling

Groundwater samples should be collected in the shortest possible time while maintaining sampling integrity.

1.12.4.1 Field Measurements

At a minimum, three field measurements must be conducted on each sample point after purging: pH, specific conductivity, and temperature. A separate bottle or beaker should be used for these measurements. These bottles may be reused, if thoroughly rinsed with DI water before use. A phosphate detergent wash followed by a DI water rinse may be required if the sampled waters are significantly contaminated. All results must be recorded on the field form, noting units to three significant figures. (e.g., pH meters must be able to provide a reading to the hundredths place [e.g., 7.14]).

When field measurements appear to be in error, all data must be discarded, new sample taken, and new measurements made. Errors should be crossed out with one line, initialed, and the reason for the error noted. Instruments which appear to have erroneous readings should be recalibrated.

If the values obtained are not within the normal ranges, notify the Project Manager immediately. Do not discard this sample, as regulatory requirements specify that analysis be performed on it. Additional samples may be requested by the Project Manager to ascertain the cause of abnormal readings.

1.12.5 Sampling Procedures

The method to be used for sampling is usually the same as that used for purging, unless other wise specified by the Project Manager. Procedures for sampling include the same steps as those for purging, with the exception being that in sampling, the water removed from the well is placed in the sample bottles rather than being discharged.

1.12.5.1 Filling Sample Bottles

Sample bottles should be filled directly from the bailer or pump with a minimal amount of air contact. Volatile organics bottles should be headspace-free and are never field-filtered. Samples which require field filtration should be filtered in-line, if possible. Where in-line filtration is not available, laboratory-quality pre-filtration bottles should be used to collect samples. This is to assure that no sediment will be introduced into the filtered sample which could cause possible analytical errors. Pre-filtration bottles must be laboratory quality. Plastic containers should be used for inorganic parameters only.

When filling the sample bottles, these important procedures and precautions must be followed:

1. Bottle caps should be removed carefully so that the inside of the cap is not touched. Caps should never be put on the ground. Caps for VOC vials contain a Teflon lined septum. The Teflon side of the septum must be facing the sample to prevent contamination of the sample through the septum. Sample bottles and pre-filtration bottles must be laboratory-quality.

2. The sample bottles should be filled with a minimal amount of air contact, and without allowing the sampling equipment or personnel to contact the inside of the bottles. Tubing or hoses from pumps must not be placed into the sample bottles.

3. Samples which are to be filtered and preserved, should be placed in pre-filtration bottles and filled completely full to allow for any loss of water from sediment during filtering. Once filtered, sufficient space should be available in the sample bottles for the addition of required preservatives. The bottle caps should then be replaced tightly.

4. Samples which are not to be filtered and which have preservatives in the bottles when received should be completely filled with the sample with as little overflow as possible and bottle caps replaced tightly. If required preservatives have not been received in the bottles, the bottles should be filled with adequate space available in the bottles for the preservative to be added.

5. VOC vials must be filled so that they are "headspace free" (i.e., no air bubbles in the sample bottle). These sample bottles, therefore, need to be over-filled (water tension will maintain a convex water surface in the bottle). The caps for these bottles should be replaced gently, so as to eliminate any air bubbles in the sample. These bottles must then be checked, by inverting the bottles and snapping them sharply with a finger. If any air bubbles appear, open the bottle, add more water, and repeat this process until all air bubbles are absent. Do not empty the bottle and refill.

6. All sample bottles, once filtered, filled, and preserved as required, must be placed into a refrigerator or cooler with ice until ready to be shipped. Samples must be shipped to the laboratory no longer than 24 hours after they are collected. Therefore, allow time at the end of the day to get the collected samples to the courier. Other samples which have shorter holding times or which are on short turn-around time should be shipped or delivered to the laboratory at the end of the sampling day.

7. All sample bottles must be placed in direct contact with ice in accordance with WDNR directives.

8. Sample bottles, caps, or septum which fall on the ground before filling, should be thoroughly rinsed with sample water before being used.

1.12.5.2 Filtration

State guidelines may vary regarding filtration of samples in the field. However, samples that must be filtered shall be filtered through a 0.45-micron membrane filter, preferably an in-line filter cartridge. The Project Manager must alert the sampling personnel to any site-specific requirements.

Filtering is used in order to sample the ions and compounds that are dissolved in solution in the groundwater. Monitoring wells are not as fully developed as drinking water wells and often contain silts and sediment that need to be removed by filtration. If the water is not filtered, the ions and compounds that are naturally present in, or absorbed on, the suspended particles may be released when samples are preserved and analyzed. This would result in false data for the constituents that actually are present in dissolved phase in the groundwater only.

Filtration and preservation of groundwater samples is an integral part of the monitoring program. Improper techniques during this process can affect the integrity of the sample. Therefore, all possible precautions should be taken to ensure that no contamination sources are introduced during filtration or preservation.

Filtering Notes

- Filtering should be performed immediately upon collection of the samples and it should be done in the field. Where this is not possible, it should be completed as soon as possible after the sample has been taken and should be done under the most sanitary conditions available. Disposable field filters will be utilized to minimize the possibility of cross-contamination between samples.
- Any sample which is suspected or known to contain high contamination levels is to be filtered last to minimize the potential for possible cross-contamination.
- Surface water, private wells, and leachate samples are never filtered.
- Pre-filtration and filter bottles are not to be reused. Material of and use of pre-filtration bottles must be noted on the field form.

Filtration Equipment

- 0.45 µm disposable in-line filters;
- High grade water;

- Pre-filtration bottles;
- Peristaltic pump, if well is not equipped with dedicated pump;
- Miscellaneous supplies (paper towels, tools, markers, etc.);
- Parameter checklist form to ensure that there is a proper pre-filtration bottle for each analyses or series of analyses that is required for that particular sample;
- Knowledge of which samples are to be filtered for each sample point; and
- Proper preservatives (type and amount);

Filtering Procedure:

1. Filters and pre-filtration bottles are dedicated to the sample point and should arrive at the site ready for use requiring no decontamination. The pump hose may be dedicated or decontaminated between locations depending on site conditions.
2. Position the new bottle under the outlet valve of the disposable filter.
3. Place inlet end of the peristaltic pump hose into the full pre filtration bottle. Pumping the water from the pre filtration bottle through the filter via the hose. A minimum of three (3) pump cycles of water must be allowed to pass through the filter before obtaining a sample.
4. When the sample bottle is full, turn the pump off.
5. Add the proper preservative, which is attached to the bottle or the filtered sample (as stated on the COC) and recap the bottle. Recap the bottle and invert the bottle several times to mix the sample.
6. Record the necessary information on the field forms and COC after every filter change.
7. Reassemble the filter apparatus and begin process from start (1) as previously discussed for the next sample.

It is imperative that the proper filtration and preservation techniques be strictly followed. This precise care is necessary, since many of the parameters are measured in the ppb range.

1.12.5.3 QA/QC Samples

Control or external QA/QC samples will be collected and submitted for analysis in accordance with SOP 07-04-04, including trip blanks, field blanks, and duplicate samples.

1.13 Low-Flow Sampling Techniques

The following equipment is required to perform low flow sampling:

- Pump capable of withdrawal at a constant rate between 100 and 500 ml/min that can meet the designed lift requirements (i.e. peristaltic pump and/or bladder pump);
- In-line flow cell equipped with a multiprobe such as the QED-MP20;
- All necessary tubing required to reach the screened interval of the well and connect the pump to the flow cell;
- A flow meter or other type of water measuring device to accurately measure and monitor the discharge from the pumping well;
- Electric water level indicator(s) capable of measurement to the hundredth of a foot;
- 5 gallon pail to collect purge water; and
- Field forms and/or field notebook(s), pens, and field book.

1.14 SAMPLE COLLECTION

Prior to sample collection, any equipment that comes into contact with the water should be cleaned and/or decontaminated according to the Equipment Decontamination SOP 07-04-05. The cleaned equipment should not come into contact with the ground or any other surface that may impart contaminants. Estimate the length of tubing needed to reach the screened portion of the well(s). Make sure that the equipment (flow cell probe) is properly calibrated in accordance with SOP 07-11-01.

Lower the sampling tube near the center of the screen, if the tubing is too high the pump will draw water from the column of water in the casing, if it is too low the pump may pick up sediment at the bottom of the well.

The pumping rate will be determined by the sampler in the field, because each well is different and will allow different sampling rates without disturbing natural conditions. The pumping rate should be determined by:

- Start the pump at 100 milliliters per minute (mL/min) or the lowest rate possible;
- Slowly increased the pumping rate and monitor drawdown;

- If drawdown is rapid, lower the pumping rate until drawdown decreases and stabilizes; and
- Continue to increase the pumping until drawdown occurs and stabilizes.

Once drawdown stabilizes, measurements of the water quality indicators can be taken. When using an in-line flow through cell (e.g., QED MP-20), measurements of the water should be made once every time the cell volume has been pumped. Therefore, if the volume of the flow through cell is 500 mL/min and the pumping rate is 250 mL/min, one reading should be taken every 2 minutes.

Continue monitoring the water quality indicators until three consecutive readings taken over several minutes have fallen within the rages of the parameters in the table below.

Parameter	**Stabilization Criterion**
pH	± 0.2 pH units
Conductivity	± 3% of reading
Dissolved Oxygen	± 10% of reading or/ ± 0.2 mg/L whichever is greater
Eh or ORP	± 20 mV

The meter will beep when the parameters have stabilized. Now it is time to sample. Before sampling, disconnect the flow through cell, then collect the sample from the tubing as normal for each type of sample. Do not change the flow rate after stabilization as this may disrupt the flow of water from the formation.

1.15 References

ASTM International, D4448-01 Standard Guide for Sampling Groundwater Monitoring Wells

ASTM International, D5903-96(2001) Standard Guide for Planning and Preparing for a Groundwater Sampling Event

ASTM International, D6089-97(2003)e1 Standard Guide for Documenting a Ground-Water Sampling Event

ASTM International, D6301-03 Practice for the Collection of Samples of Filterable and Nonfilterable Matter in Water

ASTM International, D6452-99(2005) Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations

ASTM International, D6564-00(2005) Standard Guide for Field Filtration of Ground-Water Samples

ASTM International, D6634-01 Guide for the Selection of Purging and Sampling Devices for Ground-Water Monitoring Wells

ASTM International, D6771-02 Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

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AQUIFER TESTING

1.1 Scope and Application

This standard is applicable to field evaluation of aquifer hydraulic conductivity. Variations in the hydraulic conductivity within or between formations or strata can create irregularities in groundwater flow paths. Formations of high hydraulic conductivity represent areas of greater groundwater flow and, therefore, zones of potential preferred contaminant migration. Further, anisotropy within strata or formations affects the magnitude and direction of groundwater flow. Thus, information on hydraulic conductivities is necessary to evaluate preferential flow paths and groundwater velocity.

Hydrogeologic assessments should contain data on the hydraulic conductivities of the significant formations underlying the site as measured in monitoring wells. It may be beneficial to use numerical or laboratory methods to augment results of field tests. However, field methods provide the best definition of the horizontal hydraulic conductivity in most cases. Field methods differ from laboratory methods which measure vertical hydraulic conductivity, typically in Shelby tube samples.

1.2 Health and Safety Warnings

Follow Natural Resource Technology, Inc. (NRT) Health and Safety (H&S) standard operating procedures (SOPs) when working with potentially hazardous material or with material of unknown origin,. Project-specific H&S plans will contain additional practices, if necessary, that are necessary to mitigate project- or site-specific hazards.

1.3 Methods

1.3.1 Field Methods

Varieties of procedures are available for evaluating hydraulic conductivity in the field. ASTM D4043-96(2004) Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well

Techniques should be consulted in selecting an appropriate test method. Field methods for collecting hydraulic conductivity data are described in a number of ASTM standard practices:

- D2434-68(2000) Test Method for Permeability of Granular Soils (Constant Head)
- D4044-96(2002) Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers
- D4050-96(2002) Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems
- D4104-96(2004) Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)
- D4105-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method
- D4106-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method
- D4511-00 Test Method for Hydraulic Conductivity of Essentially Saturated Peat
- D4630-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test
- D4631-95(2000) Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique
- D5269-96(2002) Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method
- D5270-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers
- D5472-93(2005) Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well
- D5473-93(2000) Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer

- D5720-95(2002) Practice for Static Calibration of Electronic Transducer-Based Pressure Measurement Systems for Geotechnical Purposes
- D5785-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)
- D5786-95(2000) Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems
- D5850-95(2000) Test Method for (Analytical Procedure) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells
- D5855-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well
- D5881-95(2005) Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)
- D5912-96(2004) Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)
- D5920-96(2005) Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method
- D6028-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer Taking into Consideration Storage of Water in Leaky Confining Beds by Modified Hantush Method
- D6029-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer and a Leaky Confining Bed with Negligible Storage by the Hantush-Jacob Method
- D6030-96(2002) Guide for Selection of Methods for Assessing Groundwater or Aquifer Sensitivity and Vulnerability
- D6034-96(2004) Test Method (Analytical Procedure) for Determining the Efficiency of a Production Well in a Confined Aquifer from a Constant Rate Pumping Test
- D6391-99(2004) Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials Using Two Stages of Infiltration from a Borehole

1.3.1.1 Single Well Tests

Hydraulic conductivity can be determined in the field using a variety of test methods, each addressing specific conditions and/or data collection objectives. These methods are commonly referred to as bail down or slug tests and are performed by adding or removing a slug (known volume) of water from a well and observing the recovery of the water surface to its original level. Similar results can be achieved by pressurizing the well casing, depressing the water level, and suddenly releasing the pressure to simulate removal of water from the well. One method is described by McLane, et. al. (1990) and is contained in references to the Standard Practices.

When reviewing information obtained from single well tests, several criteria should be considered. First, they are run on one well and, as such, the information is limited to the geologic area directly adjacent to the screen. Second, the vertical extent of screening will control the part of the geologic formation that is being analyzed during the test. That part of the column above or below the screen and sand filter pack interval that has not been tested may also have to be tested for hydraulic conductivity. Third, the methods used to collect the information obtained from single well tests should be adequate to accurately measure parameters such as changing static water (prior to initiation, during, and following completion of the test), the amount of water removed from the well, and the elapsed time of recovery. This is especially important in highly permeable formations where pressure transducers and high speed recording equipment may need to be used.

Observation wells in which the well screen intersects the water table (i.e. water table wells) will be tested only by methods involving removal of water from the well in order to minimize the potential for well screen filter pack interference. Addition of water to a monitor well is appropriate only to piezometer installation. However, the addition of water to any monitoring well shall be avoided whenever possible, since the addition may affect water quality in sampling events. In cases where addition of water to a well is unavoidable, it should be of document-able known quality and removed upon completion of the test.

The interpretation of the single well test data should be consistent with the existing geologic information (boring log data). The well screen and filter pack adjacent to the interval under examination should have been properly developed to ensure the removal of fines or correct deleterious drilling effects.

It is important that bail down tests be of sufficient duration to provide representative measures of hydraulic conductivity. Staff should be aware of initial rapid water level recovery during a bail down test which may represent drainage of the filter pack material around the well screen. This is of particular concern in wells screened in silty clay formations. These data points should be ignored when selecting the appropriate data points to establish a water level recovery slope.

Data from bail down tests shall be analyzed on NRT's Aqtesolv software using the Bouwer and Rice (1976) method of calculation. Each time the software is used, a standard set of data points with a known solution will be entered to assure the user and software are both making proper calculations.

1.3.1.2 Multiple Well Tests

Multiple well tests, more commonly referred to as pumping tests, are performed by pumping water from one well and observing the resulting drawdown in nearby wells. Tests conducted with wells screened in the same water-bearing formation provide hydraulic conductivity data. Tests conducted with wells screened in different water-bearing zones furnish information concerning hydraulic communication between units. Multiple well tests for hydraulic conductivity are advantageous because they characterize a greater proportion of the subsurface and thus provide a greater amount of detail. Multiple well tests are subject to similar constraints to those listed above for single well tests. Some additional problems that should have been considered in conducting a multiple well test include: (1) storage of potentially contaminated water pumped from the well system, and (2) potential effects of groundwater pumping on existing waste plumes. The geologic constraints should be considered to interpret the pumping test results. Incorrect assumptions regarding geology may translate into incorrect estimations of hydraulic conductivity.

1.3.2 Laboratory Methods

Laboratory analysis of undisturbed samples (e.g. Shelby tube) provides values of vertical hydraulic conductivity. When laboratory methods are to be used, the specific ASTM Standard Practice shall be referenced in samples provided to subcontractors. ASTM methods shall be consulted to assure that test methods specified are applicable to the sample to be tested.

1.4 Controlled Pumping Tests

The most representative method for determining aquifer characteristics is by controlled aquifer pumping tests, because these tests stress a much larger volume of the formation than slug tests and laboratory tests. Pumping tests require a higher level of effort and expense than other types of aquifer tests, and are not always justified. As an example, slug tests may be acceptable for site characterization, whereas pumping tests may be performed to support remedial design or modeling.

Aquifer characteristics that may be obtained from pumping tests include transmissivity (T), hydraulic conductivity (K), specific yield (Sy) for unconfined aquifers, and storage coefficient (S) for confined aquifers. These parameters can be determined by graphical solutions and computerized programs, such as Aqtesolv®. The purpose of this standard operating procedure (SOP) is to outline the protocol for conducting a controlled pumping test.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required dependent on site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

1.4.1 Summary

If possible, continuously monitor pre-test water levels at the test site for about one week prior to performance of the pump test. This information allows for the determination of the barometric efficiency of the aquifer, as well as noting changes in head due to recharge or pumping in the area adjacent to the well. Prior to initiating the long-term pump test, a step test (Section 7.0) is performed to estimate the greatest flow rate that may be sustained by the pump well.

After the pumping well has recovered from the step test, the long-term pumping test begins. At the beginning of the test, the discharge rate is set as quickly and accurately as possible. The water levels in the pumping well and observation wells are recorded following a set schedule. Data is entered on the Pump Test - Data Acquisition and Manual Data Entry forms (Appendix A). The duration of the test is determined by project needs and aquifer properties; typically three days or until water levels become constant.

1.4.2 Interferences and Potential Problems

Prior to conducting a pumping test, efforts should be made to anticipate and resolve interferences and potential problems that could affect the aquifer or the test. These problems could be caused by changing atmospheric conditions, impact of local potable wells, contaminants in the aquifer, etc. Note that if it is necessary for a neighboring well to continue pumping, it should be pumped at a constant rate and not started or stopped for the duration of the test.

1.4.3 Equipment/Apparatus

The following equipment is required to perform a pump test:

- Pump (and generator if required) capable of withdrawal at a constant or predetermined variable rate that can meet the designed pumpage rate and lift requirements
- Water pressure transducers and data logger (bring transducers for the pumping well and each observation well as well as extras in case of malfunction)
- A flow meter or other type of water measuring device to accurately measure and monitor the discharge from the pumping well
- Sufficient hose or pipe to convey discharge outside the recharge area of the pumping well and observation wells
- Electric water level indicator(s) capable of measurement to the hundredth of a foot
- Watch or stopwatch with second hand
- Barometer (some groundwater multiprobes include a barometer)
- Tape Measure of appropriate length based on distance to observation wells.
- Flashlights, lanterns, alarm clock, electrical tape
- Semi-log graph paper, Attachment A forms, pens, and field book

1.4.4 Pumping Discharge

If a pumping test will be conducted in an area with contaminated groundwater, special arrangements must be made for proper handling, treatment, and disposal of the water. The preferred method is to discharge to a sanitary sewer, with prior approval.

Uncontaminated groundwater discharge generated during a pumping test should be sent to storm or sanitary sewers, abiding by all applicable regulations. If there are no sewers in the vicinity of the pumping well, the discharge may be sent to a river or pond. If the previously mentioned discharge options are not available, the groundwater may be discharged to the ground surface under either of the following conditions:

- The aquifer being tested is confined; or
- The end of the discharge hose/pipe is outside of the cone of depression created by the pumping well when testing an unconfined aquifer.

1.4.5 Pre-Test Procedures

The hydrostratigraphy of the aquifer should be fully characterized prior to performance of the test to identify formation thickness, whether it is confined or unconfined, whether confining layers are leaky and to identify any lateral boundaries that may influence results.

Fill in the Pump Test Data Acquisition Form (Appendix A) as completely as possible prior to execution of the test. Specifically, well construction details for the pumping well and all of the observation wells.

If the pumping test occurs at a site where existing production and/or monitoring wells will be used, confirm that the locations and screened intervals of the wells are within the same aquifer, and meet the requirements of the method of analysis.

If possible, continuously measure water levels in the pumping well and all observation wells for a period at least equal to the length of the test. These measurements will establish a pre-pumping trend. The trend should be similar in all wells. A well with an unusual trend may indicate some local stress in the aquifer.

When barometric records are available, changes in barometric pressure will be recorded during the test in order to correct water levels for any possible fluctuations that may occur due to changing atmospheric conditions. Pre-test water level trends are projected for the duration of the test. These trends and/or barometric changes are used to "correct" water levels during the test so they are representative of the hydraulic response of the aquifer due to pumping of the test well.

1.4.6 Step Test

The step drawdown test is performed to determine the maximum pumping rate that the pumping well can sustain and the minimum pumping rate necessary to assure drawdown in the observation wells. The pumping and observation wells are equipped with transducers prior to the test. The test is then performed by pumping at a low rate, relative to the expected final rate of pumpage, until drawdown in the pumping well stabilizes. The rate is then increased again until drawdown in the pumping well stabilizes (step 2). A minimum of three steps will be tested; the duration of each step will be similar, and should be between 30 minutes and 2 hours.

The data are then plotted on semi-log paper or on a computer. The minimum sustainable pumping rate that yields drawdown in the closest observation wells will be used as the target-pumping rate for the long-term test. These data may also be used to determine aquifer properties and well loss in the pumping well.

1.4.7 Pump Test

1.4.7.1 Time Intervals

Commence the long-term pumping test after the pumping well has fully recovered from the step test. Place transducers into the observation wells prior to starting the test and allow time for them to equilibrate to the water temperature within the well. At the beginning of the test, the discharge rate should be set as quickly and accurately as possible. Record the pumping and observation well water levels with transducers and a data logger(s) set to record logarithmically. As backup in case of transducer malfunction, manually record water levels on field forms and/or field notebooksaccording to the schedules in Tables 1 and 2:

TABLE 1.
Time Intervals for Measuring Drawdown in the Pumped Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-10	0.5-1
10-15	1
15-60	5

60-300	30
300-1440	60
1440-termination	480

TABLE 2.
Time Intervals for Measuring Drawdown in an Observation Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-60	2
60-120	5
120-240	10
240-360	30
360-1440	60
1440-termination	480

1.4.7.2 Water Level Measurements

Water levels will be measured as specified in the Well Level Measurement SOP. During the early part of the test, sufficient personnel are required to initiate the pumping test data loggers and assist with manual water level measurements of the pumping well and flow rate measurements. Manual measurements are required as a backup to and verification of the data logger(s). After the first two hours, one to two people are usually sufficient to continue the test. It is not necessary that readings at the wells be taken simultaneously. It is very important that depth to water readings be measured accurately and the exact time of readings is recorded. A typical aquifer pump test form is shown in Appendix A.

During a pumping test, the following data must be recorded accurately on the aquifer test data form.

1) Project ID - A number assigned to identify a specific site.

2) Well ID - The location of the well in which water level measurements are being taken.

3) Distance and Direction from Pumped Well - Distance and azimuth to each observation well from the pumping well in feet.

4) NRT Personnel - The personnel conducting the pumping test.

5) Pumping Start and End Date/Time - The date when the pumping began, and start time using a 24-hour clock.

6) Initial Static Water Level (Test Start) - Depth to water, to the nearest 0.01 feet, in the observation well at the beginning of the pumping test.

7) Test End Date/Time - The date and time when water level readings were discontinued.

8) Final Static Water Level (Test End) - Depth to water, to the nearest 0.01 feet, in the observation well at the end of the pumping test.

9) Target Pumping Rate

10) Measurement Methods - Type of pump, type of data logger(s) used to record water levels, transducer ID number, and acquisition rate (i.e. data recorded on a log scale)

11) Notes - Appropriate observations or information which has not been recorded elsewhere, including notes on sampling, pH readings, and conductivity readings.

12) Elapsed Time (min) - Time of manual measurement record from time 0.00 (start of test) recorded in minutes and seconds.

13) Depth to Water (ft) – Manual depth to water measurement, to the nearest 0.01 feet, in the observation well at the time of the water level measurement.

14) Flow Rate (gal/min) - Flow rate of pump measured from an orifice, weir, flow meter, container, or other type of water measuring device.

1.4.7.3 Test Duration

The duration of the test is determined by the needs of the project and properties of the aquifer. One simple test for determining adequacy of data is when the log-time versus drawdown for the most distant observation well begins to plot as a straight line on the semi-log graph paper. There are several exceptions to this simple rule of thumb; therefore, it should be considered a minimum criterion. Different hydrogeologic conditions can produce straight-line trends on log-time versus drawdown plots. In general, longer tests produce more definitive results. Duration of one to three days is desirable, followed by a similar period of monitoring the recovery of the water level. Unconfined aquifers and partially penetrating wells may have shorter test durations. Knowledge of the local hydrogeology, combined with a clear understanding of the overall project objectives is necessary in judging appropriate test duration. There is no need to continue the test once the water levels in the observation wells stabilize.

The recovery of water levels following pumping phase may be measured and recorded for a period of time equal to the pumping phase. The frequency of the water level measurements should be similar to the frequency of water level measurements during the pumping phase (Table 1).

1.4.8 Post Operation

The following activities are performed after completion of water level recovery measurements.

- Decontaminate and/or dispose of equipment per Sampling Equipment Decontamination SOP.
- When using an electronic data-logger, use the following procedures:
- Stop logging sequence
- Check file size, print data, and/or save memory to a reliable storage device (i.e. hard drive or USB drive): Backup the data as soon as possible upon completion of a test!
- Do not clear the memory of the transducer until the data has been saved onto a hard drive
- Review field forms for completeness.
- Replace testing equipment in storage containers
- Check sampling equipment and supplies. Repair or replace all broken or damaged equipment.
- Interpret pumping/recovery test field results.

1.5 Calculations

Upload the data from the test into a spreadsheet to be entered into a computerized program, such as Aqtesolv®. Use the information entered into the Data Acquisition Form to complete the computer analysis of the data. There are several accepted methods for determining aquifer properties such as transmissivity, storativity, and conductivity. The appropriate method to use is dependent on the characteristics of the aquifer being tested (confined, unconfined, leaky confining layer etc.). When reviewing pump test data, the following text and/or documents may be used to determine the method most appropriate to your case:

- Analysis and Evaluation of Pumping Test Data (Kruseman and Ridder, 1989)
- Applied Hydrogeology (Fetter, 2000)
- Groundwater and Wells (Driscoll, 1986)
- ASTM D4105-96(2002)
- ASTM D4106-96(2002)

1.6 Quality Assurance/ Quality Control

Gauges, transducers, flow meters, and other equipment used in the pumping tests will be calibrated before use at the site. Copies of the documentation of instrumentation calibration will be filed with the test data records. The calibration records will consist of laboratory measurements and, if necessary, any on-site zero adjustment and/or calibration that were performed. Where possible, all flow and measurement meters will be checked on-site using a container of measured volume and stopwatch; the accuracy of the meters must be verified before testing proceeds.

1.7 Data Reduction and Interpretation

Data collected from single well tests will be analyzed by methods described by Bouwer and Rice (1976). Multiple well data can be analyzed by a variety of methods, depending on the specific geologic and well parameters. Texts such as Driscoll (1986) or other well hydraulics references should be consulted for selection of the proper method of data analysis.

In reviewing hydraulic conductivity measurements, the following criteria should be considered to evaluate the accuracy or completeness of information.

- Values of hydraulic conductivity between wells in similar lithologies should generally not exceed one order of magnitude difference.

- Hydraulic conductivity determinations based upon multiple well tests are preferred. Multiple well tests provide more complete information because they characterize a greater portion of the subsurface.

- Use of single well tests will require that more individual tests be conducted at different locations to sufficiently define hydraulic conductivity variation across the site.

- Hydraulic conductivity information generally provides average values for the entire area across a well screen. For more depth discrete information, well screens will have to be shorter. If the average hydraulic conductivity for a formation is required, entire formations may have to be screened, or data taken from overlapping clusters.

It is important that measurements define hydraulic conductivity both vertically and horizontally across the site. Laboratory tests may be necessary to ascertain vertical hydraulic conductivity in saturated formations or strata. Results from boring logs should also be used to characterize the site geology. Zones of high permeability or fractures identified from drilling logs should be considered in the determination of hydraulic conductivity. Additionally, information from boring logs can be used to refine the data generated by single well or pumping tests.

1.8 References

Bouwer, H., and Rice, R.C., "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with completely or Partially Penetrating Wells", Water Res. Res., 12 p. 423-428, 1976.

Driscoll, F. G., 1986, Groundwater and Wells, Johnson Division, St. Paul, MN, 1089 p.

McLane, G. A., D. A. Harrity, K. O. Thomsen, "Slug Testing In Highly Permeable Aquifers Using a Pneumatic Method", Hazardous Materials Control Research Institute, Conference Proceedings, November, 1990, pp 300-303.

ASTM International, D2434-68(2000) Test Method for Permeability of Granular Soils (Constant Head)

ASTM International, D4043-96(2004) Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques

ASTM International, D4044-96(2002) Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers

ASTM International, D4050-96(2002) Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems

ASTM International, D4104-96(2004) Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)

ASTM International, D4105-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method

ASTM International, D4106-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method

ASTM International, D4511-00 Test Method for Hydraulic Conductivity of Essentially Saturated Peat

ASTM International, D4630-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test

ASTM International, D4631-95(2000) Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique

ASTM International, D5269-96(2002) Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method

ASTM International, D5270-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers

ASTM International, D5472-93(2005) Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well

ASTM International, D5473-93(2000) Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer

ASTM International, D5720-95(2002) Practice for Static Calibration of Electronic Transducer-Based Pressure Measurement Systems for Geotechnical Purposes

ASTM International, D5785-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)

ASTM International, D5786-95(2000) Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems

ASTM International, D5850-95(2000) Test Method for (Analytical Procedure) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells

ASTM International, D5855-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well

ASTM International, D5881-95(2005) Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)

ASTM International, D5912-96(2004) Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)

ASTM International, D5920-96(2005) Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method

ASTM International, D6028-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer Taking into Consideration Storage of Water in Leaky Confining Beds by Modified Hantush Method

ASTM International, D6029-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer and a Leaky Confining Bed with Negligible Storage by the Hantush-Jacob Method

ASTM International, D6030-96(2002) Guide for Selection of Methods for Assessing Groundwater or Aquifer Sensitivity and Vulnerability

ASTM International, D6034-96(2004) Test Method (Analytical Procedure) for Determining the Efficiency of a Production Well in a Confined Aquifer from a Constant Rate Pumping Test

ASTM International, D6391-99(2004) Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials Using Two Stages of Infiltration from a Borehole

Attachment B

Boring Logs and Well Completion Reports

SOIL BORING LOG INFORMATION

NATURAL
RESOURCE
TECHNOLOGY

Page 1 of 2

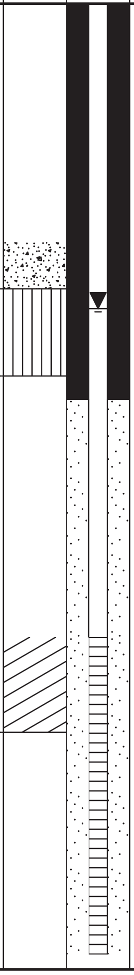
Facility/Project Name: Ameren Duck Creek Energy Center
License/Permit/Monitoring Number:
Boring Number: GS1

Boring Drilled By: Name of crew chief (first, last) and Firm: Bruno Williamson, Testing Service Corporation
Date Drilling Started: 4/23/2013
Date Drilling Completed: 4/23/2013
Drilling Method: hollow stem auger

Common Well Name: GS1
Final Static Water Level: 599.8 Feet (NAVD)
Surface Elevation: 603.6 Feet (NAVD)
Borehole Diameter: 6.3 inches

Local Grid Origin ☒ (estimated: ☒) or Boring Location ☐
State Plane N, E S / C / [✓ N]
1/4 of 1/4 of Section , T N, R
Lat ____° ____' ________"
Long ____° ____' ________"
Local Grid Location: 1393568.77 Feet ☒ N ☐ S 2345228.96 Feet ☒ E ☐ W

Facility ID:
County: Fulton
State: Illinois
Civil Town/City/ or Village: Canton



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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			1 2											
1 SS	24 20	17 17 20 16	3	3 - 3.6' **FILL, WELL-GRADED SAND:** SW, mine spoils, black, well graded fine to coarse sand sized weathered shale, some fine to coarse gravel sized pieces, 20% silt sized grains, dry.	(FILL) SW									
			4 5 6 7	3.6 - 4.7' **FILL, SILT:** ML, light olive brown (2.5Y 5/4, 2.5Y 5/6), gray (2.5Y 5/1), 20-30% fine sand, trace medium and coarse sand, trace fine gravel (subrounded to subangular), noncohesive, nonplastic, dry.	(FILL) ML				4 4.5 4.5					
2 SS	24 14	2 3 4 6	8 9	8 - 9.2' **FILL, LEAN CLAY:** CL, same colors as above, 20-30% silt, trace fine to coars sand, trace fine gravel, cohesive, low to medium plasticity, moist, trace angular fine gravel sized gray shale at bottom of interval.	(FILL) CL				0.5					
			10 11 12											

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

Signature

Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

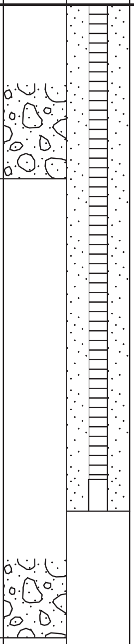
SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number GS1

Page 2 of 2

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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
3 SS	24 13	4 4 4 10	13 14	13 - 14.2' **FILL, WELL-GRADED GRAVEL:** GW, mine spoils, gray (2.5Y 5/1) and black (2.5Y 2.5/1), mostly weathered shale (angular, fissile), fine to coarse gravel sized pieces, 20-30% sand sized grains, 10-20% silt sized grains, dry to moist. 14' wet.	(FILL) GW									
			15 16 17											
4 SS	24 12	1 3 4 5	18 19 20	19 - 20' **FILL, WELL-GRADED GRAVEL:** GW, mine spoils, as above, gray (2.5Y 5/1), mostly weathered shale, fine to coarse gravel sized pieces, increased silt and sand sized grains, moist to wet. 20' End of Boring.	(FILL) GW									



SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

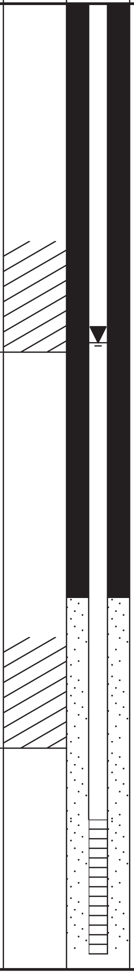
Facility/Project Name: Ameren Duck Creek Energy Center
License/Permit/Monitoring Number:
Boring Number: GS2

Boring Drilled By: Name of crew chief (first, last) and Firm: Bruno Williamson, Testing Service Corporation
Date Drilling Started: 4/23/2013
Date Drilling Completed: 4/25/2013
Drilling Method: hollow stem auger

Common Well Name: GS2
Final Static Water Level: 606.4 Feet (NAVD)
Surface Elevation: 610.7 Feet (NAVD)
Borehole Diameter: 6.3 inches

Local Grid Origin ☒ (estimated: ☒) or Boring Location ☐
State Plane N, E S / C / [✓ N]
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location: 1394468.62 Feet ☒ N ☐ S 2345208.76 Feet ☒ E ☐ W

Facility ID:
County: Fulton
State: Illinois
Civil Town/City/ or Village: Canton



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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			1 2											
1 SS	24 17	1 1 3 3	3 4 5 6 7	3 - 4.4' **FILL, LEAN CLAY:** CL, light olive brown (2.5Y 5/6), olive yellow (2.5Y 6/6), yellowish brown (10YR 5/4), 10% dark gray (2.5Y 4/1) mottling, 10-20% silt, trace plant roots at top of interval, cohesive, low to medium plasticity, dry to moist. 4' piece of fine gravel size black shale.	(FILL) CL				0.5 2					
2 SS	24 17	2 2 2 3	8 9 10 11 12	8 - 9.4' **FILL, LEAN CLAY:** CL, as above, trace coarse sand, trace fine gravel, dry to moist. 8.2' nodule of brown silt (0.5" diameter).	(FILL) CL				0.25 0.25					

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

Signature

Firm Natural Resource Technology
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Tel: (262) 523-9000
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SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number GS2

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		Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
3 SS	24 17	0 1 2 2	13	13 - 14.4' **FILL, LEAN CLAY:** CL, as above, trace coarse sand and fine gravel, trace coarse sand and fine gravel sized gray and black shale fragments, trace coarse gravel sized silt nodules, dry to moist.	(FILL) CL				0.25 0.25					
4 SS	24 7	1 2 2 3	18	18 - 18.6' **FILL, SILT:** to **LEAN CLAY:** ML, as above with increased silt content, 40-60% silt, dry. 18.3' 30-40% fine to coarse gravel sized gray weathered shale.	(FILL) ML				1					
5 SS	24 15	1 1 3 3	23	23 - 24.3' **FILL, LEAN CLAY:** CL, yellowish brown (10YR 5/8), light olive brown (2.5Y 5/6), 10-20% silt (silt appears as fine gravel sized nodules, gray (2.5Y 5/1)),trace coarse sand and fine gravel, trace coarse sand and fine gravel sized gray weathered shale pieces, cohesive, low to medium plasticity, dry to moist.	(FILL) CL				0.5 0.4					
6 SS	24 18	1 2 3 4	28	28 - 28.5' **FILL, SILT:** to **LEAN CLAY:** ML, dark gray to black (2.5Y 4/1, 2.5Y 5/1, 2.5Y 3/1, 2.5Y 2.5/1), 30-40% clay, cohesive, low plasticity, dry.	(FILL) ML									
				28.5 - 29.5' **FILL, LEAN CLAY:** CL, as above, dry to moist.	(FILL) CL				0.75 0.5					
			30	30' End of Boring.										

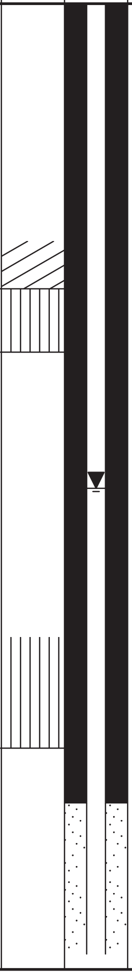
SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Page 1 of 2

Facility/Project Name: Ameren Duck Creek Energy Center
License/Permit/Monitoring Number:
Boring Number: GS3
Boring Drilled By: Name of crew chief (first, last) and Firm: Bruno Williamson, Testing Service Corporation
Date Drilling Started: 4/24/2013
Date Drilling Completed: 4/24/2013
Drilling Method: hollow stem auger
Common Well Name: GS3
Final Static Water Level: 600.4 Feet (NAVD)
Surface Elevation: 606.5 Feet (NAVD)
Borehole Diameter: 6.3 inches
Local Grid Origin ☒ (estimated: ☒) or Boring Location ☐
State Plane N, E S / C / [✓ N]
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location: 1396880.48 Feet ☒ N ☐ S 2345234.43 Feet ☒ E ☐ W
Facility ID:
County: Fulton
State: Illinois
Civil Town/City/ or Village: Canton

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		Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
1 SS	24 16	1 2 3 3	3	3 - 3.6' **FILL, LEAN CLAY:** CL, native, light olive brown (2.5Y 5/6), cohesive, medium to high plastcity, moist.	(FILL) CL				0.4					
			4	3.6 - 4.4' **SILT:** to **LEAN CLAY:** ML, native, loess, gray (2.5Y 6/1), 1/8" layers of dark yellowish brown (10YR 4/6) fines, mostly silt, 10-20% clay, cohesive, nonplastic to low plasticity, moist.	ML				0.75					
2 SS	24 17	1 2 3 4	8	8 - 9.4' **SILT:** to **LEAN CLAY:** ML, native, loess, as above, gray (2.5Y 6/1), 30% dark yellowish brown (10YR 4/6) mottling, increased clay content (20-30%), cohesive, low to medium plasticity, dry to moist.	ML				1 1					



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

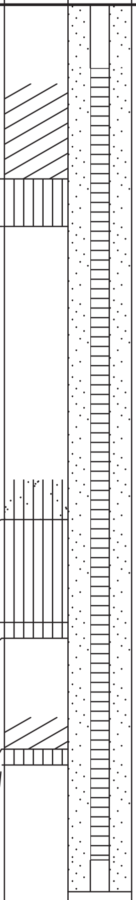
Signature

Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number GS3



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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
3 SS	24 20	2 3 5 6	13	13 - 14.2' **LEAN CLAY:** CL, native, dark yellowish brown (10YR 4/6), 30-40% silt, trace fine to coarse subangular sand, cohesive, low to medium plasticity, dry.	CL				2.5 0.5					
			14	14.2 - 14.8' **SILT:** to **LEAN CLAY:** ML, native, as above, trace angular fine gravel, dry to moist.	ML				0.25					
			15											
			16											
			17											
4 SS	24 24	5 5 6 6	18	18 - 18.5' **SANDY SILT:** s(ML), native, dark yellowish brown (10YR 4/6), mostly silt, 10-20% very fine sand, trace coarse sand and root debris, dry to moist.	s(ML)									
			19	18.5 - 19.8' **SILT:** ML, native, pale yellow (5Y 7/3), 20% yellowish brown (10YR 5/6) mottling, 10-20% clay, cohesive, nonplastic to low plasticity, trace subangular coarse sand and fine gravel.	ML				2.25 1.75 1.5					
			20	19.8 - 20' **SILT:** to **LEAN CLAY:** ML, native, gray (2.5Y 6/1), 5-15% clay, trace subangular coarse sand and fine gravel, cohesive, nonplastic to low plastcity, dry to moist.	ML									
5 SS	24 7	4 10 16 33	21	21 - 21.4' **LEAN CLAY:** CL, light olive brown (2.5Y 5/6), trace fine gravel, trace silt, trace root debris, cohesive, medium to high plasticity.	CL									
			22	21.4 - 21.6' **SILT:** to **LEAN CLAY:** ML, as above, gray (2.5Y 6/1), dry to moist.	ML									
			23	23' End of Boring.										

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Facility/Project Name Ameren Duck Creek Energy Center	License/Permit/Monitoring Number	Boring Number GS4

Boring Drilled By: Name of crew chief (first, last) and Firm Bruno Williamson Testing Service Corporation	Date Drilling Started 4/26/2013	Date Drilling Completed 4/26/2013	Drilling Method hollow stem auger

Common Well Name GS4	Final Static Water Level 589.2 Feet (NAVD)	Surface Elevation 599.7 Feet (NAVD)	Borehole Diameter 6.3 inches

Local Grid Origin ☒ (estimated: ☒) or Boring Location ☐

State Plane N, E S / C / [✓ N]

1/4 of 1/4 of Section , T N, R

Lat ____° ____' ________"

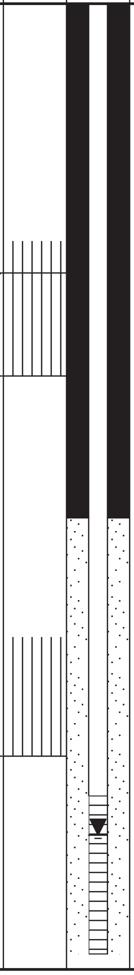
Long ____° ____' ________"

Local Grid Location

1396872.9 Feet ☒ N ☐ S 2345593.01 Feet ☒ E ☐ W

Facility ID	County Fulton	State Illinois	Civil Town/City/ or Village Canton

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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 SS	24 20	1 6 8 7	3	3 - 3.4' **SILT:** to **LEAN CLAY:** ML, native, dark yellowish brown (10YR 4/6), 10% gray (2.5Y 6/1) mottling, cohesive, nonplasticity to low plasticity, dry.	ML				1.75					
				3.4 - 4.7' **SILT:** ML, native, loess, gray (2.5Y 6/1), trace dark yellowish brown (10YR 4/6) mottling at top 3" of layer, 10-20% clay, noncohesive, nonplastic, dry to moist.	ML				2 2					
2 SS	24 17	1 3 4 6	8	8 - 9.5' **SILT:** to **LEAN CLAY:** ML, dark yellowish brown (10YR 4/6), 20-30% gray (2.5Y 6/1) mottling, 40-60% clay, 5-15% fine to coarse angular sand, cohesive, low plasticity.	ML				0.5 1					



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

Signature	Firm Natural Resource Technology 23713 W. Paul Road Suite D, Pewaukee, WI 53072 Tel: (262) 523-9000 Fax: (262) 523-9001

SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL
RESOURCE
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Boring Number GS4

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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
3 SS	24 21	2 5 7 13	13 14	13 - 14.7' **SILT:** to **LEAN CLAY:** ML, yellowish brown (10YR 5/6), 20-30% clay, 20-30% fine to coarse sand, trace fine subangular gravel, cohesive, nonplastic to low plasticity, dry to moist.	ML				0.5 0.25 0.75					
			15 16 17											
4 SS	24 20	2 5 7 13	18 19	18 - 19.7' **SILTY SAND:** SM, light olive brown (2.5Y 5/4), 30-40% silt (noncohesive, nonplastic), trace coarse sand, trace fine angular gravel, moist.	SM				3.25 2 1.25					
			20	20' End of Boring.										

SOIL BORING LOG INFORMATION

NATURAL
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TECHNOLOGY

Page 1 of 2

Facility/Project Name: Ameren Duck Creek Energy Center
License/Permit/Monitoring Number:
Boring Number: GS5
Boring Drilled By: Name of crew chief (first, last) and Firm: Bruno Williamson, Testing Service Corporation
Date Drilling Started: 4/26/2013
Date Drilling Completed: 4/26/2013
Drilling Method: hollow stem auger
Common Well Name: GS5
Final Static Water Level: 600.6 Feet (NAVD)
Surface Elevation: 610.5 Feet (NAVD)
Borehole Diameter: 6.3 inches
Local Grid Origin ☒ (estimated: ☒) or Boring Location ☐
State Plane N, E S / C / [✓ N]
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location: 1394892.91 Feet ☒ N ☐ S 2345473.04 Feet ☒ E ☐ W
Facility ID:
County: Fulton
State: Illinois
Civil Town/City/ or Village: Canton

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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 SS	24 13	1 2 2 2	3	3 - 4.1' **FILL, SILT:** to **LEAN CLAY:** ML, dark grayish brown (2.5Y 4/2), olive yellow (2.5Y 6/6), olive yellow (2.5Y 6/8), 30-40% clay, cohesive, nonplastic to low plasticity, dry to moist. 3.5' coarse gravel sized piece of weathered black shale, trace fine to coarse sand, trace fine gravel, some gravel pieces are weathered gray shale.	(FILL) ML				0.25					
2 SS	24 13	2 2 2 3	8	8 - 9.1' **FILL, SILT:** to **LEAN CLAY:** ML, same colors as above, 20-30% clay, 5-15% fine to coarse sand sized material, trace black fine gravel sized shale pieces, trace gray very weathered fine gravel sized shale pieces, cohesive, nonplastic to low plasticity, dry to moist.	(FILL) ML				1.5 0.5					

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

Signature

Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

Template: SOIL BORING PEW ADDRESS - Project: DUCK CREEK.GPJ

SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number GS5

Page 2 of 2

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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
3 SS	24 15	2 2 3 4	13	13 - 13.2' **FILL, SILT:** to **LEAN CLAY:** ML, as above.	(FILL) ML				0.75					
			14	13.2 - 14.3' **FILL, SILT:** ML, mine spoils, mostly silt, same colors as above, fine sand to coarse gravel sized gray weathered shale, noncohesive, nonplastic, moist.	(FILL) ML				1.5					
			15											
			16											
			17											
4 SS	24 11	0 2 4 3	18	18 - 18.9' **FILL, SILT:** ML, mine spoils, mostly silt, same colors as above, 20-40% fine sand to coarse gravel sized gray weathered shale, 10-20% clay (olive brown (2.5Y 4/3)), cohesive, nonplastic to low plasticity, moist to wet.	(FILL) ML									
			19						1.5					
			20											
			21											
			22											
5 SS	24 13	0 1 2 3	23	23 - 24.1' **FILL, SILT:** to **LEAN CLAY:** ML, mine spoils, as above, same colors as above, 20-30% clay (olive brown (2.5Y 4/3)), 10-30% fine sand to coarse gravel sized weathered shale, cohesive, low plasticity, moist to wet.	(FILL) ML				3 1					
			24											
			25	25' End of Boring.										

SOIL BORING LOG INFORMATION

Natural Resource Technology

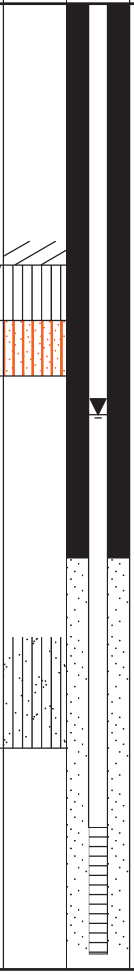
Facility/Project Name: Ameren Duck Creek Energy Center
License/Permit/Monitoring Number:
Boring Number: GS6

Boring Drilled By: Name of crew chief (first, last) and Firm: Bruno Williamson, Testing Service Corporation
Date Drilling Started: 4/22/2013
Date Drilling Completed: 4/26/2013
Drilling Method: hollow stem auger

Common Well Name: GS6
Final Static Water Level: 595.1 Feet (NAVD)
Surface Elevation: 600.3 Feet (NAVD)
Borehole Diameter: 6.3 inches

Local Grid Origin ☒ (estimated: ☒) or Boring Location ☐
State Plane N, E S / C / [✓ N]
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location: ☒ N ☒ E
1393712.7 Feet ☐ S 2345458.67 Feet ☐ W

Facility ID:
County: Fulton
State: Illinois
Civil Town/City/ or Village: Canton



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		Soil Properties: Compressive Strength (tsf)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
1 SS	24 20	0 2 4 4	3	3 - 3.3' **FILL, LEAN CLAY:** CL, very dark grayish brown (2.5Y 3/2), trace medium sand, trace root debris.	(FILL) CL									
				3.3 - 4' **FILL, SILT:** ML, olive brown (2.5Y 4/4), 10-20% very dark grayish brown (2.5Y 3/2) mottling, 10-20% light olive brown (2.5Y 5/6) mottling, mostly silt, 20-30% fine sand, 10-20% clay, nonplastic to low plasticity, dry.	(FILL) ML				0.5					
			4	4 - 4.7' **FILL, SILTY SAND:** SM, as above, mostly fine sand, 30-40% silt.	(FILL) SM				2.75					
2 SS	24 17	2 2 1 3	8	8 - 9.4' **FILL, SANDY SILT:** s(ML), very dark grayish brown (2.5Y 3/2), black (2.5Y 2.5/1), light gray (2.5Y 7/2), olive (5Y 5/3), 30-40% very fine sand, trace fine to medium sand, trace fine rounded gravel, trace angular shale pieces, cohesive, nonplastic to low plasticity, dry to moist.	(FILL) s(ML)				0.75					

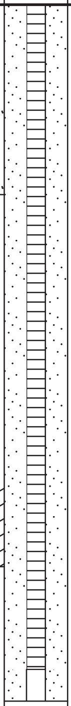
I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature
Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

SOIL BORING LOG INFORMATION SUPPLEMENT

Boring Number GS6

Page 2 of 3



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	Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
3 SS	24 16	0 2 2 4	13	13 - 14.4' **FILL, SANDY SILT:** s(ML), as above.	(FILL) s(ML)						
4 SS	24 13	0 2 3 3	18	18 - 19.1' **FILL, LEAN CLAY:** CL, same colors as above, 20-30% silt, 15-20% very fine sand, trace fine to medium sand, trace fine gravel, cohesive, low to medium plasticity, dry to moist.	(FILL) CL	2.5 0.5					
5 SS	24 14	0 2 3 3	23	23 - 24' **FILL, LEAN CLAY:** CL, as above, moist.	(FILL) CL	4.25					
			24	24 - 24.3' **FILL, SANDY SILT:** s(ML), same colors as above, mostly silt, 30-40% very fine sand, 10-20% clay, nonplastic to low plasticity, dry to moist.	(FILL) s(ML)	0.75					
6 SS	24 16	0 7 8 6	28	28 - 29.3' **FILL, SILTY SAND:** SM, mine spoils, dark gray (2.5Y 4/1), gray (2.5Y 5/1), mostly poorly graded fine to medium sand sized grains, 10-20% silt, some gravel sized weathered black shale (angular), nonplastic fines, non cohesive fines, moist to wet.	(FILL) SM						

Depth In Feet: 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32

SOIL BORING LOG INFORMATION SUPPLEMENT

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Boring Number GS6

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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
7 SS	24 14	4 4 6 13	33	33 - 33.5' **FILL, SILT:** to **LEAN CLAY:** ML, brown (10YR 4/3), dark brown (10YR 3/3), light gray (2.5Y 7/1), black (2.5Y 2.5/1), 30-40% clay, 10-20% fine to medium sand, cohesive, nonplastic to low plasticity. 33.5 - 34.2' **FILL, SILT:** ML, dark gray (2.5Y 4/1), 10-20% fine to medium sand, noncohesive, nonplastic, dry.	(FILL) ML (FILL) ML									
8 SS	24 17	2 5 6 6	38	38 - 39.4' **FILL, SILT:** ML, gray (2.5Y 5/1), dark brown (10YR 3/3), 20-30% clay, 10-15% sand, cohesive nonplastic, moist.	(FILL) ML				0.5					
9 SS	24 17	0 2 3 4	43	43 - 44.4' **FILL, LEAN CLAY:** CL, dark gray to black (2.5Y 4/1, 2.5Y 5/1, 2.5Y 2.5/1), light olive brown (2.5Y 5/6), very dark grayish brown (2.5Y 3/2), 30-40% silt, 10-20% fine sand, trace fine gravel, trace coarse sand, cohesive, low plasticity, moist.	(FILL) CL									
			45	45' End of Boring.										

SOIL BORING LOG INFORMATION

NATURAL
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TECHNOLOGY

Page 1 of 2

Facility/Project Name: Ameren Duck Creek Energy Center
License/Permit/Monitoring Number:
Boring Number: GS7

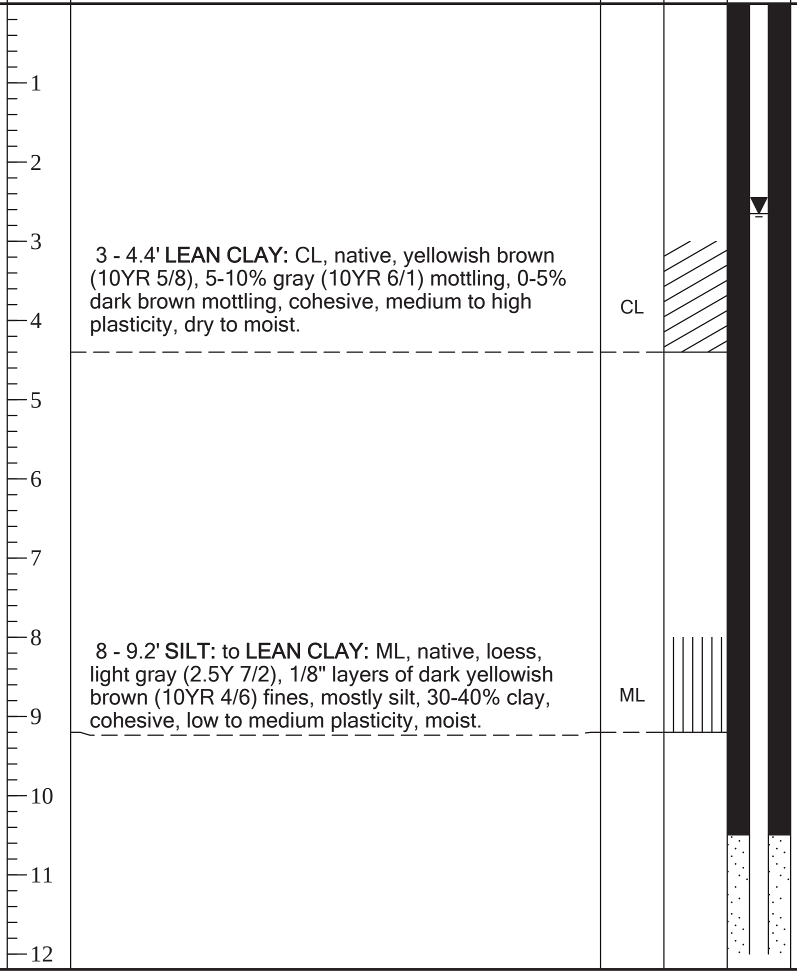
Boring Drilled By: Name of crew chief (first, last) and Firm: Bruno Williamson, Testing Service Corporation
Date Drilling Started: 4/24/2013
Date Drilling Completed: 4/24/2013
Drilling Method: hollow stem auger

Common Well Name: GS7
Final Static Water Level: 615.3 Feet (NAVD)
Surface Elevation: 618.0 Feet (NAVD)
Borehole Diameter: 6.3 inches

Local Grid Origin ☒ (estimated: ☒) or Boring Location ☐
State Plane N, E S / C / [✓ N]
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location: 1397057 Feet ☒ N ☐ S 2344178.35 Feet ☒ E ☐ W

Facility ID:
County: Fulton
State: Illinois
Civil Town/City/ or Village: Canton

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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 SS	24 17	2 3 4 4		3 - 4.4' **LEAN CLAY:** CL, native, yellowish brown (10YR 5/8), 5-10% gray (10YR 6/1) mottling, 0-5% dark brown mottling, cohesive, medium to high plasticity, dry to moist.	CL				0.5 0.4					
2 SS	24 14	2 3 3 3		8 - 9.2' **SILT:** to **LEAN CLAY:** ML, native, loess, light gray (2.5Y 7/2), 1/8" layers of dark yellowish brown (10YR 4/6) fines, mostly silt, 30-40% clay, cohesive, low to medium plasticity, moist.	ML				0.5 0.5					



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

Signature

Firm Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

SOIL BORING LOG INFORMATION SUPPLEMENT

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TECHNOLOGY

Boring Number GS7

Page 2 of 2

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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
3 SS	24 16	2 3 3 4	13 14	13 - 14.4' **SILT:** to **LEAN CLAY:** ML, native, as above, dark grayish brown (2.5Y 4/2), 40-60% clay, dry to moist.	ML				0.4 0.25					
			15 16 17											
4 SS	24 17	2 3 5 6	18 19	18 - 19.4' **LEAN CLAY:** to **SILT:** CL, native, gray (2.5Y 6/1), 20-30% dark yellowish brown (10YR 4/6) mottling, 30-40% silt, trace fine to coarse sand, trace fine gravel, cohesive, medium plasticity, dry.	CL				1 0.75					
			20 21 22											
5 SS	24 18		23	23 - 23.5' **LEAN CLAY:** CL, native, dark brown (2.5Y 3/3), trace fine sand, cohesive, medium to high plasticity, dry to moist.	CL				0.5					
			24	23.5 - 24.1' **LEAN CLAY:** CL, olive (5Y 5/4), trace coarse sand and fine gravel, cohesive, medium to high plasticity, moist.	CL				0.25					
			25	24.1 - 24.5' **SANDY SILT:** s(ML), olive (5Y 5/6), mostly silt, some fine to coarse sand, 20-30% fine to coarse gravel, dry. 25' End of Boring.	s(ML)									

SOIL BORING LOG INFORMATION

NATURAL RESOURCE TECHNOLOGY

Page 1 of 2

Facility/Project Name: Ameren Duck Creek Energy Center
License/Permit/Monitoring Number:
Boring Number: GS8

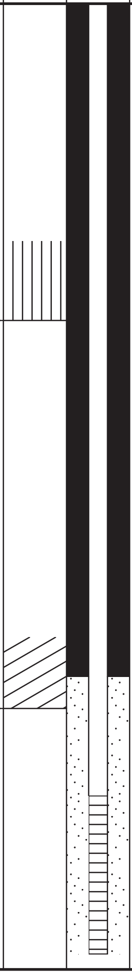
Boring Drilled By: Name of crew chief (first, last) and Firm: Bruno Williamson, Testing Service Corporation
Date Drilling Started: 4/26/2013
Date Drilling Completed: 4/26/2013
Drilling Method: hollow stem auger

Common Well Name: GS8
Final Static Water Level: 585.5 Feet (NAVD)
Surface Elevation: 598.7 Feet (NAVD)
Borehole Diameter: 6.3 inches

Local Grid Origin ☒ (estimated: ☒) or Boring Location ☐
State Plane N, E S / C / [✓ N]
1/4 of 1/4 of Section , T N, R
Lat ° ' "
Long ° ' "
Local Grid Location: 1394644.23 Feet ☒ N ☐ S 2347610.14 Feet ☒ E ☐ W

Facility ID:
County: Fulton
State: Illinois
Civil Town/City/ or Village: Canton

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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			1											
			2											
1 SS	24 12	3 5 6 5	3	3 - 4' **FILL, SILT:** ML, gray (2.5Y 6/1), olive yellow (2.5Y 6/6), 10% brownish yellow (10YR 6/6), 40-60% fine sand to coarse gravel size black and gray weathered shale, 30-40% clay at top of unit (olive brown (2.5Y 4/3)), trace root debris, noncohesive, nonplastic, dry to moist.	(FILL) ML				0.5					
			4											
			5											
			6											
			7											
2 SS	24 11	0 1 3 3	8	8 - 8.9' **FILL, LEAN CLAY:** to **SILT:** CL, reworked clay, gray (2.5Y 6/1), light olive brown (2.5Y 5/6), olive yellow (2.5Y 6/6), trace black (2.5Y 2.5/1) and yellowish brown (10YR 5/8), 30-40% silt, trace fine sand to fine gravel sized black weathered shale, cohesive, low to medium plasticity, dry to moist. 8.8' piece of weathered gray shale (1" diameter).	(FILL) CL				0.25					
			9											
			10											
			11											
			12											



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

Signature:
Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

SOIL BORING LOG INFORMATION SUPPLEMENT

NATURAL RESOURCE TECHNOLOGY

Boring Number GS8

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		Compressive Strength (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
3 SS	24 17	0 1 1 3	13 14	13 - 14.4' **FILL, LEAN CLAY:** to **SILT:** CL, reworked clay, as above, dry to moist. 13.2' mostly silt, gray (2.5Y 6/1), noncohesive, nonplastic (2" thick).	(FILL) CL				0.25 0.25					
			15 16 17											
4 SS	24 11	0 1 2 3	18 19	18 - 18.9' **FILL, LEAN CLAY:** to **SILT:** CL, reworked clay, as above, same colors as above, dry to moist. 18.6' mostly silt, moist (4" thick).	(FILL) CL				0.25					
			20	20' End of Boring.										

Natural Resource Technology

MONITORING WELL CONSTRUCTION

Facility/Project Name: Ameren Duck Creek Energy Center

Local Grid Location of Well: 1393568.77 ft. ☒ N. ☐ S. 2345228.96 ft. ☒ E. ☐ W.

Well Name: GS1

Facility License, Permit or Monitoring No.:

Local Grid Origin ☒ (estimated: ☒) or Well Location ☐

Lat. ° ' " Long. ° ' " or

Facility ID:

St. Plane ft. N, ft. E. S / C / [✓ N]

Date Well Installed: 04/23/2013

Section Location of Waste/Source: 1/4 of 1/4 of Sec. , T. N, R. ☐ E ☐ W

Type of Well: Well Code 11/mw

Well Installed By: (Person's Name and Firm): Bruno Williamson, Testing Service Corporation

Distance from Waste/ Source: ft.

State: Illinois

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known

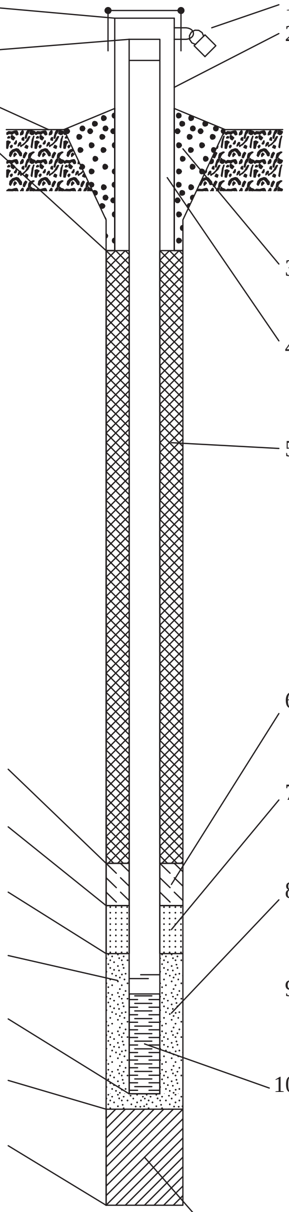
Gov. Lot Number:

A. Protective pipe, top elevation 606.21 ft. MSL

B. Well casing, top elevation 606.05 ft. MSL

C. Land surface elevation 603.6 ft. MSL

D. Surface seal, bottom 602.6 ft. MSL or 1.0 ft.



12. USCS classification of soil near screen:
    - GP ☐ GM ☐ GC ☐ GW ☒ SW ☐ SP ☐
    - SM ☐ SC ☐ ML ☐ MH ☐ CL ☒ CH ☐
    - Bedrock ☐
13. Sieve analysis attached? ☐ Yes ☒ No
14. Drilling method used: Rotary ☐ Hollow Stem Auger ☒ Other ☐
15. Drilling fluid used: Water ☐ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☒
16. Drilling additives used? ☐ Yes ☒ No

    Describe
17. Source of water (attach analysis, if required): n/a

E. Bentonite seal, top 602.6 ft. MSL or 1.0 ft.

F. Fine sand, top ft. MSL or ft.

G. Filter pack, top 598.6 ft. MSL or 5.0 ft.

H. Screen joint, top 595.6 ft. MSL or 8.0 ft.

I. Well bottom 585.2 ft. MSL or 18.4 ft.

J. Filter pack, bottom 585.2 ft. MSL or 18.4 ft.

K. Borehole, bottom 583.6 ft. MSL or 20.0 ft.

L. Borehole, diameter 6.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
    - a. Inside diameter: 4.0 in.
    - b. Length: 5.0 ft.
    - c. Material: Steel ☒ Other ☐
    - d. Additional protection? ☒ Yes ☐ No
      If yes, describe: Two 6' steel bollards and 7' PVC marker.
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
    - b. Lbs/gal mud weight . . . Bentonite-sand slurry ☐
    - c. Lbs/gal mud weight . . . Bentonite slurry ☐
    - d. % Bentonite . . . Bentonite-cement grout ☐
    - e. Ft^3 volume added for any of the above
    - f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
    - b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
    - c. Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
    - a.
    - b. Volume added ft^3
8. Filter pack material: Manufacturer, product name & mesh size
    - a.
    - b. Volume added ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
    - a. Screen Type: Factory cut ☐ Continuous slot ☐ Prepacked Screen Other ☒
    - b. Manufacturer
    - c. Slot size: 0.100 in.
    - d. Slotted length: 10.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

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

Date Modified: 5/14/2013

Signature

Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name: Ameren Duck Creek Energy Center

Local Grid Location of Well: 1394468.62 ft. ☒ N. ☐ S. 2345208.76 ft. ☒ E. ☐ W.

Well Name: GS2

Facility License, Permit or Monitoring No.:

Local Grid Origin ☒ (estimated: ☒) or Well Location ☐

Lat. ____ ° ____ ' ______ " Long. ____ ° ____ ' ______ " or

St. Plane ____________ ft. N, ____________ ft. E. S / C / [✓ N]

Facility ID:

Date Well Installed: 04/25/2013

Section Location of Waste/Source: _____1/4 of _____ 1/4 of Sec. _____, T. _____ N, R. _____ ☐ E ☐ W

Type of Well: Well Code 11/mw

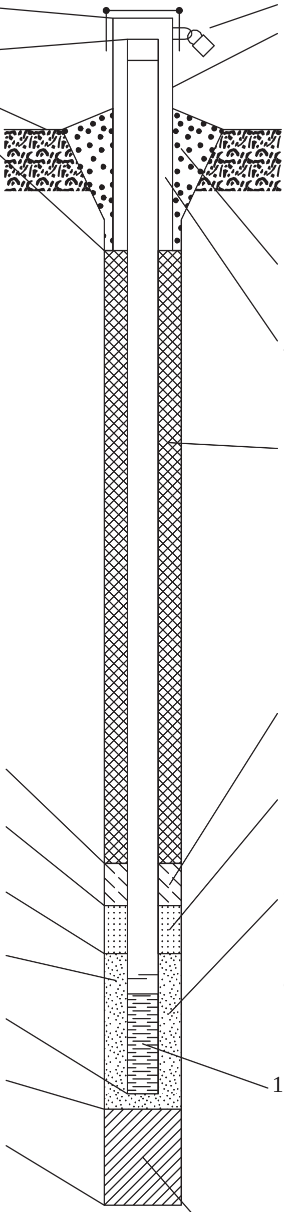
Well Installed By: (Person's Name and Firm): Bruno Williamson, Testing Service Corporation

Distance from Waste/Source: ft.

State: Illinois

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known

Gov. Lot Number:



A. Protective pipe, top elevation 612.73 ft. MSL

B. Well casing, top elevation 612.41 ft. MSL

C. Land surface elevation 610.7 ft. MSL

D. Surface seal, bottom 609.7 ft. MSL or 1.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☒ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☒ Other ☐

15. Drilling fluid used: Water ☐ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☒

16. Drilling additives used? ☐ Yes ☒ No

Describe ______________

17. Source of water (attach analysis, if required): n/a

E. Bentonite seal, top 609.7 ft. MSL or 1.0 ft.

F. Fine sand, top ______ ft. MSL or ______ ft.

G. Filter pack, top 603.2 ft. MSL or 7.5 ft.

H. Screen joint, top 600.4 ft. MSL or 10.3 ft.

I. Well bottom 590.0 ft. MSL or 20.7 ft.

J. Filter pack, bottom 590.0 ft. MSL or 20.7 ft.

K. Borehole, bottom 580.7 ft. MSL or 30.0 ft.

L. Borehole, diameter 6.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

1. Cap and lock? ☒ Yes ☐ No

2. Protective cover pipe:
   - a. Inside diameter: 4.0 in.
   - b. Length: 5.0 ft.
   - c. Material: Steel ☒ Other ☐
   - d. Additional protection? ☒ Yes ☐ No
     If yes, describe: Two 6' steel bollards and 7' PVC marker.

3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐

4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒

5. Annular space seal: a. Granular/Chipped Bentonite ☒
   - b. ______Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   - c. ______Lbs/gal mud weight . . . Bentonite slurry ☐
   - d. ______% Bentonite . . . Bentonite-cement grout ☐
   - e. __________Ft^3 volume added for any of the above
   - f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒

6. Bentonite seal: a. Bentonite granules ☐
   - b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   - c. ______________ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
   - a. ______________
   - b. Volume added ________ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
   - a. ______________
   - b. Volume added ________ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐

10. Screen material: Schedule 40 PVC
    - a. Screen Type: Factory cut ☐ Continuous slot ☐ Prepacked Screen Other ☒
    - b. Manufacturer ______________
    - c. Slot size: 0.100 in.
    - d. Slotted length: 10.0 ft.

11. Backfill material (below filter pack): None ☒ Other ☐

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

Date Modified: 5/14/2013

Signature

Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

Natural Resource Technology

MONITORING WELL CONSTRUCTION

Facility/Project Name: Ameren Duck Creek Energy Center

Local Grid Location of Well: 1396880.48 ft. ☒ N. ☐ S. 2345234.43 ft. ☒ E. ☐ W.

Well Name: GS3

Facility License, Permit or Monitoring No.

Local Grid Origin ☒ (estimated: ☒) or Well Location ☐

Lat. ____° ____' ______" Long. ____° ____' ______" or

St. Plane __________ ft. N, __________ ft. E. S / C / [✓ N]

Facility ID

Date Well Installed: 04/24/2013

Section Location of Waste/Source

_____1/4 of _____ 1/4 of Sec. _____, T. _____ N, R. _____ ☐ E ☐ W

Type of Well: Well Code 11/mw

Well Installed By: (Person's Name and Firm)
Bruno Williamson
Testing Service Corporation

Distance from Waste/Source ft.

State: Illinois

Location of Well Relative to Waste/Source
u ☐ Upgradient s ☐ Sidegradient
d ☐ Downgradient n ☐ Not Known

Gov. Lot Number

A. Protective pipe, top elevation 608.90 ft. MSL

B. Well casing, top elevation 608.72 ft. MSL

C. Land surface elevation 606.5 ft. MSL

D. Surface seal, bottom 605.5 ft. MSL or 1.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☒ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☒
__________ Other ☐

15. Drilling fluid used: Water ☐ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☒

16. Drilling additives used? ☐ Yes ☒ No

Describe __________

17. Source of water (attach analysis, if required):
n/a

E. Bentonite seal, top 605.5 ft. MSL or 1.0 ft.

F. Fine sand, top ______ ft. MSL or ______ ft.

G. Filter pack, top 596.4 ft. MSL or 10.1 ft.

H. Screen joint, top 593.7 ft. MSL or 12.8 ft.

I. Well bottom 583.3 ft. MSL or 23.2 ft.

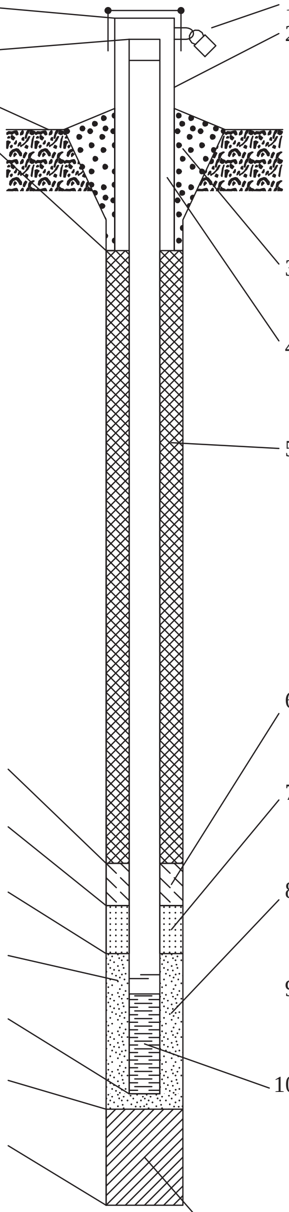
J. Filter pack, bottom 583.3 ft. MSL or 23.2 ft.

K. Borehole, bottom 583.5 ft. MSL or 23.0 ft.

L. Borehole, diameter 6.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No

2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒
   __________ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: 7' PVC marker.

3. Surface seal: Bentonite ☐
   Concrete ☒
   __________ Other ☐

4. Material between well casing and protective pipe:
   Bentonite ☐
   Sand Other ☒

5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ______Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ______Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ______% Bentonite . . . Bentonite-cement grout ☐
   e. ________Ft^3 volume added for any of the above
   f. How installed: Tremie ☐
   Tremie pumped ☐
   Gravity ☒

6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. __________ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
   a. __________
   b. Volume added ________ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
   a. __________
   b. Volume added ________ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   __________ Other ☐

10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☐
   Continuous slot ☐
   Prepacked Screen Other ☒
   b. Manufacturer __________
   c. Slot size: 0.100 in.
   d. Slotted length: 10.0 ft.

11. Backfill material (below filter pack): None ☒
   __________ Other ☐

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

Date Modified: 5/14/2013

Signature

Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name: Ameren Duck Creek Energy Center

Local Grid Location of Well: 1396872.9 ft. ☒ N. ☐ S. 2345593.01 ft. ☒ E. ☐ W.

Well Name: GS4

Facility License, Permit or Monitoring No.

Local Grid Origin ☒ (estimated: ☒) or Well Location ☐

Lat. ____ ° ____ ' ____ " Long. ____ ° ____ ' ____ " or

St. Plane ____ ft. N, ____ ft. E. S / C / [✓ N]

Facility ID

Date Well Installed: 04/26/2013

Section Location of Waste/Source

____ 1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W

Type of Well: Well Code 11/mw

Well Installed By: (Person's Name and Firm)
Bruno Williamson
Testing Service Corporation

Distance from Waste/Source ____ ft.

State: Illinois

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known

Gov. Lot Number

A. Protective pipe, top elevation 602.04 ft. MSL

B. Well casing, top elevation 601.86 ft. MSL

C. Land surface elevation 599.7 ft. MSL

D. Surface seal, bottom 598.7 ft. MSL or 1.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☒ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☒ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☒
____ Other ☐

15. Drilling fluid used: Water ☐ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☒

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required):
n/a

E. Bentonite seal, top 598.7 ft. MSL or 1.0 ft.

F. Fine sand, top ____ ft. MSL or ____ ft.

G. Filter pack, top 593.2 ft. MSL or 6.5 ft.

H. Screen joint, top 589.7 ft. MSL or 10.0 ft.

I. Well bottom 579.3 ft. MSL or 20.4 ft.

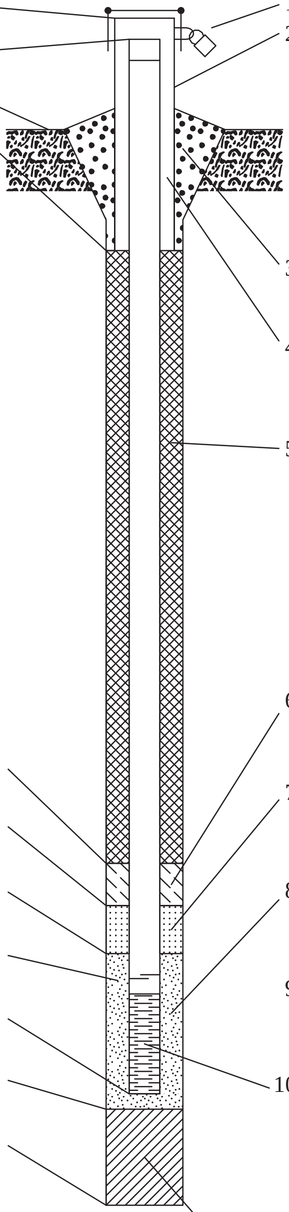
J. Filter pack, bottom 579.3 ft. MSL or 20.4 ft.

K. Borehole, bottom 579.7 ft. MSL or 20.0 ft.

L. Borehole, diameter 6.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No

2. Protective cover pipe:
 a. Inside diameter: 4.0 in.
 b. Length: 5.0 ft.
 c. Material: Steel ☒
 ____ Other ☐
 d. Additional protection? ☒ Yes ☐ No
 If yes, describe: 7' PVC marker.

3. Surface seal: Bentonite ☐
Concrete ☒
____ Other ☐

4. Material between well casing and protective pipe:
Bentonite ☐
Sand Other ☒

5. Annular space seal: a. Granular/Chipped Bentonite ☒
 b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
 c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
 d. ____ % Bentonite . . . Bentonite-cement grout ☐
 e. ____ Ft^3 volume added for any of the above
 f. How installed: Tremie ☐
 Tremie pumped ☐
 Gravity ☒

6. Bentonite seal: a. Bentonite granules ☐
 b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
 c. ____ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
 a. ____
 b. Volume added ____ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
 a. ____
 b. Volume added ____ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒
Flush threaded PVC schedule 80 ☐
____ Other ☐

10. Screen material: Schedule 40 PVC
 a. Screen Type: Factory cut ☐
 Continuous slot ☐
 Prepacked Screen Other ☒
 b. Manufacturer ____
 c. Slot size: 0.100 in.
 d. Slotted length: 10.0 ft.

11. Backfill material (below filter pack): None ☒
____ Other ☐

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

Date Modified: 5/14/2013

Signature

Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

Natural Resource Technology

MONITORING WELL CONSTRUCTION

Facility/Project Name: Ameren Duck Creek Energy Center

Local Grid Location of Well: 1394892.91 ft. ☒ N. ☐ S. 2345473.04 ft. ☒ E. ☐ W.

Well Name: GS5

Facility License, Permit or Monitoring No.

Local Grid Origin ☒ (estimated: ☒) or Well Location ☐

Lat. ____° ____' ____" Long. ____° ____' ____" or

St. Plane ________ ft. N, ________ ft. E. S / C / [✓ N]

Facility ID

Date Well Installed: 04/26/2013

Section Location of Waste/Source

____1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W

Type of Well: Well Code 11/mw

Well Installed By: (Person's Name and Firm): Bruno Williamson, Testing Service Corporation

Distance from Waste/Source ____ ft.

State: Illinois

Location of Well Relative to Waste/Source

u ☐ Upgradient s ☐ Sidegradient

d ☐ Downgradient n ☐ Not Known

Gov. Lot Number

A. Protective pipe, top elevation 612.03 ft. MSL

B. Well casing, top elevation 611.87 ft. MSL

C. Land surface elevation 610.5 ft. MSL

D. Surface seal, bottom 609.5 ft. MSL or 1.0 ft.

12. USCS classification of soil near screen:

GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐

SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐

Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☒ No

14. Drilling method used: Rotary ☐

Hollow Stem Auger ☒

Other ☐

15. Drilling fluid used: Water ☐ 0 2 Air ☐

Drilling Mud ☐ 0 3 None ☒

16. Drilling additives used? ☐ Yes ☒ No

Describe ____________

17. Source of water (attach analysis, if required): n/a

E. Bentonite seal, top 609.5 ft. MSL or 1.0 ft.

F. Fine sand, top ______ ft. MSL or ______ ft.

G. Filter pack, top 598.7 ft. MSL or 11.8 ft.

H. Screen joint, top 595.1 ft. MSL or 15.4 ft.

I. Well bottom 584.7 ft. MSL or 25.8 ft.

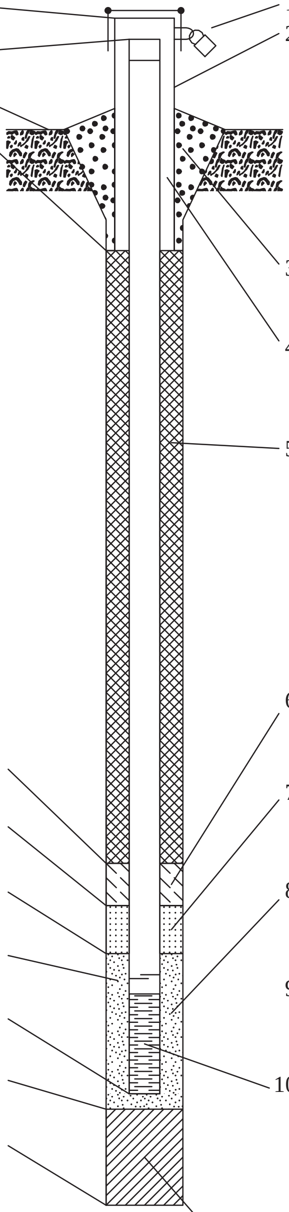
J. Filter pack, bottom 584.7 ft. MSL or 25.8 ft.

K. Borehole, bottom 585.5 ft. MSL or 25.0 ft.

L. Borehole, diameter 6.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No

2. Protective cover pipe:

a. Inside diameter: 4.0 in.

b. Length: 5.0 ft.

c. Material: Steel ☒

Other ☐

d. Additional protection? ☒ Yes ☐ No

If yes, describe: 7' PVC marker.

3. Surface seal: Bentonite ☐

Concrete ☒

Other ☐

4. Material between well casing and protective pipe:

Bentonite ☐

Sand Other ☒

5. Annular space seal: a. Granular/Chipped Bentonite ☒

b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐

c. ____Lbs/gal mud weight . . . Bentonite slurry ☐

d. ____% Bentonite . . . Bentonite-cement grout ☐

e. ______Ft^3 volume added for any of the above

f. How installed: Tremie ☐

Tremie pumped ☐

Gravity ☒

6. Bentonite seal: a. Bentonite granules ☐

b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒

c. ____________ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size

a. ____________

b. Volume added ______ ft^3

8. Filter pack material: Manufacturer, product name & mesh size

a. ____________

b. Volume added ______ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒

Flush threaded PVC schedule 80 ☐

Other ☐

10. Screen material: Schedule 40 PVC

a. Screen Type: Factory cut ☐

Continuous slot ☐

Prepacked Screen Other ☒

b. Manufacturer ____________

c. Slot size: 0.100 in.

d. Slotted length: 10.0 ft.

11. Backfill material (below filter pack): None ☒

Other ☐

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

Date Modified: 5/14/2013

Signature

Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name: Ameren Duck Creek Energy Center

Local Grid Location of Well: 1393712.7 ft. ☒ N. ☐ S. 2345458.67 ft. ☒ E. ☐ W.

Well Name: GS6

Facility License, Permit or Monitoring No.

Local Grid Origin ☒ (estimated: ☒) or Well Location ☐

Lat. ____° ____' ____" Long. ____° ____' ____" or

St. Plane ________ ft. N, ________ ft. E. S / C / [✓ N]

Facility ID

Date Well Installed: 04/26/2013

Section Location of Waste/Source

____1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W

Type of Well: Well Code 11/mw

Well Installed By: (Person's Name and Firm)
Bruno Williamson
Testing Service Corporation

Distance from Waste/Source ____ ft.

State: Illinois

Location of Well Relative to Waste/Source
u ☐ Upgradient s ☐ Sidegradient
d ☐ Downgradient n ☐ Not Known

Gov. Lot Number

A. Protective pipe, top elevation 603.16 ft. MSL

B. Well casing, top elevation 602.77 ft. MSL

C. Land surface elevation 600.3 ft. MSL

D. Surface seal, bottom 599.3 ft. MSL or 1.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☒ No

14. Drilling method used: Rotary ☐
Hollow Stem Auger ☒
Other ☐

15. Drilling fluid used: Water ☐ 0 2 Air ☐
Drilling Mud ☐ 0 3 None ☒

16. Drilling additives used? ☐ Yes ☒ No

Describe ____________

17. Source of water (attach analysis, if required):
n/a

E. Bentonite seal, top 599.3 ft. MSL or 1.0 ft.

F. Fine sand, top ____ ft. MSL or ____ ft.

G. Filter pack, top 593.3 ft. MSL or 7.0 ft.

H. Screen joint, top 589.9 ft. MSL or 10.4 ft.

I. Well bottom 579.5 ft. MSL or 20.8 ft.

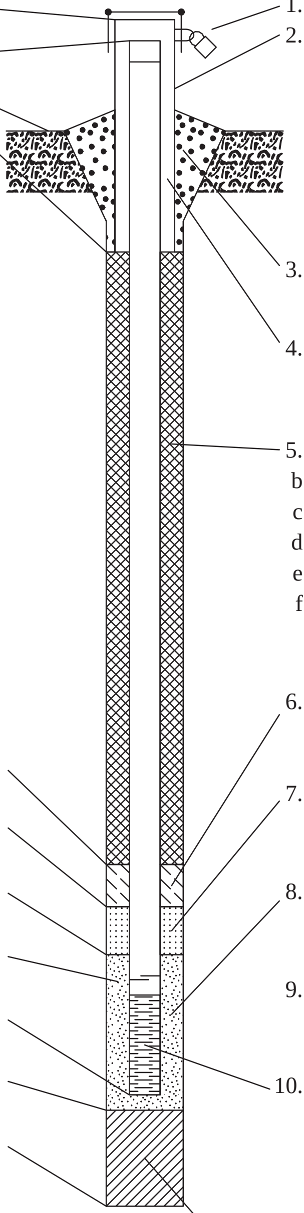
J. Filter pack, bottom 579.5 ft. MSL or 20.8 ft.

K. Borehole, bottom 555.3 ft. MSL or 45.0 ft.

L. Borehole, diameter 6.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒
   Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: 7' PVC marker.
3. Surface seal: Bentonite ☐
   Concrete ☒
   Other ☐
4. Material between well casing and protective pipe:
   Bentonite ☐
   Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____% Bentonite . . . Bentonite-cement grout ☐
   e. ____Ft^3 volume added for any of the above
   f. How installed: Tremie ☐
   Tremie pumped ☐
   Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒
   Flush threaded PVC schedule 80 ☐
   Other ☐
10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☐
   Continuous slot ☐
   Prepacked Screen Other ☒
   b. Manufacturer ____
   c. Slot size: 0.100 in.
   d. Slotted length: 10.0 ft.
11. Backfill material (below filter pack): None ☒
   Other ☐

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

Date Modified: 5/14/2013

Signature

Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name: Ameren Duck Creek Energy Center

Local Grid Location of Well: 1397057 ft. ☒ N. ☐ S. 2344178.35 ft. ☒ E. ☐ W.

Well Name: GS7

Facility License, Permit or Monitoring No.:

Local Grid Origin ☒ (estimated: ☒) or Well Location ☐

Lat. ____ ° ____ ' ____ " Long. ____ ° ____ ' ____ " or

St. Plane ____ ft. N, ____ ft. E. S / C / [✓ N]

Facility ID:

Date Well Installed: 04/24/2013

Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W

Type of Well: Well Code 11/mw

Well Installed By: (Person's Name and Firm)
Bruno Williamson
Testing Service Corporation

Distance from Waste/ Source: ft.

State: Illinois

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known

Gov. Lot Number:

A. Protective pipe, top elevation 620.24 ft. MSL

B. Well casing, top elevation 620.08 ft. MSL

C. Land surface elevation 618.0 ft. MSL

D. Surface seal, bottom 617.0 ft. MSL or 1.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☒ No

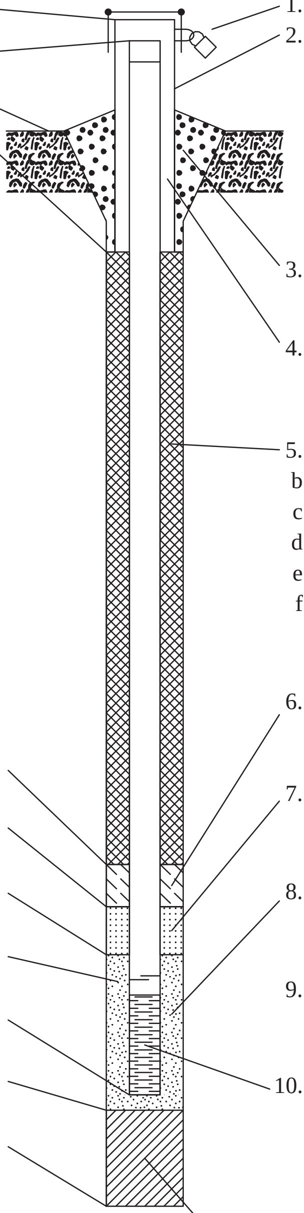
14. Drilling method used: Rotary ☐ Hollow Stem Auger ☒ ____ Other ☐

15. Drilling fluid used: Water ☐ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☒

16. Drilling additives used? ☐ Yes ☒ No

Describe ____

17. Source of water (attach analysis, if required): n/a



1. Cap and lock? ☒ Yes ☐ No

2. Protective cover pipe:
   a. Inside diameter: 4.0 in.
   b. Length: 5.0 ft.
   c. Material: Steel ☒ ____ Other ☐
   d. Additional protection? ☒ Yes ☐ No
   If yes, describe: Two 6' steel bollards and 7' PVC marker.

3. Surface seal: Bentonite ☐ Concrete ☒ ____ Other ☐

4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒

5. Annular space seal: a. Granular/Chipped Bentonite ☒
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____ % Bentonite . . . Bentonite-cement grout ☐
   e. ____ Ft^3 volume added for any of the above
   f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒

6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   c. ____ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
   a. ____
   b. Volume added ____ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ ____ Other ☐

10. Screen material: Schedule 40 PVC
   a. Screen Type: Factory cut ☐ Continuous slot ☐ Prepacked Screen Other ☒
   b. Manufacturer ____
   c. Slot size: 0.100 in.
   d. Slotted length: 10.0 ft.

11. Backfill material (below filter pack): None ☒ ____ Other ☐

E. Bentonite seal, top 617.0 ft. MSL or 1.0 ft.

F. Fine sand, top ____ ft. MSL or ____ ft.

G. Filter pack, top 607.5 ft. MSL or 10.5 ft.

H. Screen joint, top 603.4 ft. MSL or 14.6 ft.

I. Well bottom 593.0 ft. MSL or 25.0 ft.

J. Filter pack, bottom 593.0 ft. MSL or 25.0 ft.

K. Borehole, bottom 593.0 ft. MSL or 25.0 ft.

L. Borehole, diameter 6.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

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

Date Modified: 5/14/2013

Signature

Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL CONSTRUCTION

Facility/Project Name: Ameren Duck Creek Energy Center

Local Grid Location of Well: 1394644.23 ft. ☒ N. ☐ S. 2347610.14 ft. ☒ E. ☐ W.

Well Name: GS8

Facility License, Permit or Monitoring No.

Local Grid Origin ☒ (estimated: ☒) or Well Location ☐

Lat. ____° ____' ______" Long. ____° ____' ______" or

St. Plane __________ ft. N, __________ ft. E. S / C / [✓ N]

Date Well Installed: 04/26/2013

Facility ID

Section Location of Waste/Source

_____1/4 of _____ 1/4 of Sec. _____, T. _____ N, R. _____ ☐ E ☐ W

Well Installed By: (Person's Name and Firm)

Bruno Williamson

Testing Service Corporation

Type of Well: Well Code 11/mw

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known

Gov. Lot Number

Distance from Waste/Source ______ ft.

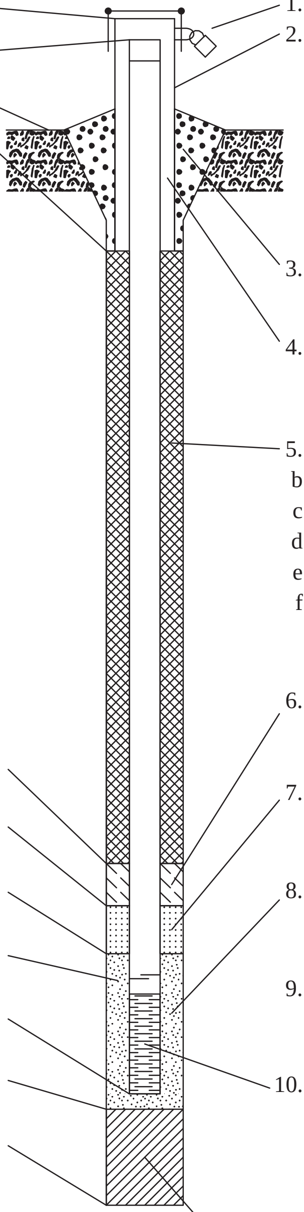
State: Illinois

A. Protective pipe, top elevation 600.95 ft. MSL

B. Well casing, top elevation 600.75 ft. MSL

C. Land surface elevation 598.7 ft. MSL

D. Surface seal, bottom 597.7 ft. MSL or 1.0 ft.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   - a. Inside diameter: 4.0 in.
   - b. Length: 5.0 ft.
   - c. Material: Steel ☒ Other ☐
   - d. Additional protection? ☒ Yes ☐ No
   - If yes, describe: Two 6' steel bollards and 7' PVC marker.
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐
4. Material between well casing and protective pipe: Bentonite ☐ Sand Other ☒
5. Annular space seal: a. Granular/Chipped Bentonite ☒
   - b. ______Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   - c. ______Lbs/gal mud weight . . . Bentonite slurry ☐
   - d. ______% Bentonite . . . Bentonite-cement grout ☐
   - e. __________Ft^3 volume added for any of the above
   - f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   - b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite chips ☒
   - c. __________ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   - a. __________
   - b. Volume added __________ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   - a. __________
   - b. Volume added __________ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐
10. Screen material: Schedule 40 PVC
    - a. Screen Type: Factory cut ☐ Continuous slot ☐ Prepacked Screen Other ☒
    - b. Manufacturer __________
    - c. Slot size: 0.100 in.
    - d. Slotted length: 10.0 ft.
11. Backfill material (below filter pack): None ☒ Other ☐

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☒ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☒ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☒ Other ☐

15. Drilling fluid used: Water ☐ 0 2 Air ☐ Drilling Mud ☐ 0 3 None ☒

16. Drilling additives used? ☐ Yes ☒ No

Describe __________

17. Source of water (attach analysis, if required): n/a

E. Bentonite seal, top 597.7 ft. MSL or 1.0 ft.

F. Fine sand, top ______ ft. MSL or ______ ft.

G. Filter pack, top 590.2 ft. MSL or 8.5 ft.

H. Screen joint, top 588.7 ft. MSL or 10.0 ft.

I. Well bottom 578.3 ft. MSL or 20.4 ft.

J. Filter pack, bottom 578.3 ft. MSL or 20.4 ft.

K. Borehole, bottom 578.7 ft. MSL or 20.0 ft.

L. Borehole, diameter 6.3 in.

M. O.D. well casing 2.38 in.

N. I.D. well casing 2.07 in.

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

Date Modified: 5/14/2013

Signature

Firm: Natural Resource Technology
23713 W. Paul Road Suite D, Pewaukee, WI 53072
Tel: (262) 523-9000
Fax: (262) 523-9001

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL DEVELOPMENT

Facility/Project Name	State	Well Name
Ameren Duck Creek Energy Center	VA	GS1

Facility License, Permit or Monitoring Number

1. Can this well be purged dry? ☒ Yes ☐ No

2. Well development method:
   - surged with bailer and bailed ☐
   - surged with bailer and pumped ☒
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed, and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - other ______ ☐

3. Time spent developing well 60 min.

4. Depth of well (from top of well casing) 20.0 ft.

5. Inside diameter of well 2.07 in.

6. Volume of water in filter pack and well casing 11 gal.

7. Volume of water removed from well 15.0 gal.

8. Volume of water added (if any) 0.0 gal.

9. Source of water added not applicable

10. Analysis performed on water added? ☐ Yes ☒ No
(If yes, attach results)

		Before Development	After Development
11. Depth to Water (from top of well casing)	a.	6.81 ft.	6.57 ft.
Date	b.	4/25/2013	4/29/2013
Time	c.	03:53 ☐ a.m. ☒ p.m.	03:50 ☐ a.m. ☒ p.m.
12. Sediment in well bottom		0.0 inches	0.0 inches
13. Water clarity		Clear ☐ Turbid ☒ (Describe) gray, very turbid	Clear ☐ Turbid ☒ (Describe) gray to cloudy gray

Fill in if drilling fluids were used and well is at solid waste facility:

	Before Development	After Development
14. Total suspended solids	mg/l	mg/l
15. COD	mg/l	mg/l

16. Well developed by: Person's Name and Firm

Jacob Walczak
Natural Resource Technology, Inc.

17. Additional comments on development:

Surged with bailer for 20 minutes. Bailed well dry three times, then pumped well dry once.

Facility Address or Owner/Responsible Party Address

Name: –
Firm: Ameren
Street:
City/State/Zip:

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

Signature:
Print Name: Jacob Walczak
Firm: Natural Resource Technology, Inc.

Template: WELL DEVELOPMENT - Project: DUCK CREEK.GPJ

Date Modified: 5/14/2013

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL DEVELOPMENT

Facility/Project Name	State	Well Name
Ameren Duck Creek Energy Center	VA	GS2

Facility License, Permit or Monitoring Number

1. Can this well be purged dry? ☒ Yes ☐ No

2. Well development method:
   - surged with bailer and bailed ☐
   - surged with bailer and pumped ☒
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed, and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - other ☐

3. Time spent developing well 60 min.

4. Depth of well (from top of well casing) 22.0 ft.

5. Inside diameter of well 2.07 in.

6. Volume of water in filter pack and well casing 10.8 gal.

7. Volume of water removed from well 12.0 gal.

8. Volume of water added (if any) 0.0 gal.

9. Source of water added not applicable

10. Analysis performed on water added? ☐ Yes ☒ No
(If yes, attach results)

		Before Development	After Development
11. Depth to Water (from top of well casing)	a.	6.17 ft.	14.32 ft.
Date	b.	4/29/2013	4/30/2013
Time	c.	02:50 ☐ a.m. ☒ p.m.	09:05 ☒ a.m. ☐ p.m.
12. Sediment in well bottom		0.0 inches	0.0 inches
13. Water clarity		Clear ☐ Turbid ☒ (Describe) tan	Clear ☒ Turbid ☐ (Describe) cloudy tan

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	mg/l	mg/l
15. COD	mg/l	mg/l

16. Well developed by: Person's Name and Firm

Jacob Walczak

Natural Resource Technology, Inc.

17. Additional comments on development:

Surged with bailer for 20 minutes. Bailed well dry once, then pumped well dry once.

Facility Address or Owner/Responsible Party Address

Name: _

Firm: Ameren

Street:

City/State/Zip:

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

Signature:

Print Name: Jacob Walczak

Firm: Natural Resource Technology, Inc.

Template: WELL DEVELOPMENT - Project: DUCK CREEK.GPJ

Date Modified: 5/14/2013

NATURAL
RESOURCE
TECHNOLOGY

MONITORING WELL DEVELOPMENT

Facility/Project Name: Ameren Duck Creek Energy Center

State: VA

Well Name: GS3

Facility License, Permit or Monitoring Number:

1. Can this well be purged dry? ☐ Yes ☒ No

2. Well development method:
   - surged with bailer and bailed ☐
   - surged with bailer and pumped ☒
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed, and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - other ____________ ☐

3. Time spent developing well 60 min.

4. Depth of well (from top of well casing) 26.0 ft.

5. Inside diameter of well 2.07 in.

6. Volume of water in filter pack and well casing 10.9 gal.

7. Volume of water removed from well 35.0 gal.

8. Volume of water added (if any) 0.0 gal.

9. Source of water added not applicable

10. Analysis performed on water added? ☐ Yes ☒ No
    (If yes, attach results)

		Before Development	After Development
11. Depth to Water (from top of well casing)	a.	8.52 ft.	20.10 ft.
Date	b.	4/30/2013	4/30/2013
Time	c.	12:15 ☐ a.m. ☒ p.m.	01:17 ☐ a.m. ☒ p.m.
12. Sediment in well bottom		0.0 inches	0.0 inches
13. Water clarity		Clear ☐ Turbid ☒ (Describe) yellowish brown	Clear ☒ Turbid ☐ (Describe) cloudy tan to tan

Fill in if drilling fluids were used and well is at solid waste facility:

	Before Development	After Development
14. Total suspended solids	mg/l	mg/l
15. COD	mg/l	mg/l

16. Well developed by: Person's Name and Firm
Jacob Walczak
Natural Resource Technology, Inc.

17. Additional comments on development:
Surged with bailer for 20 minutes, then pumped.

Facility Address or Owner/Responsible Party Address

Name: _

Firm: Ameren

Street:

City/State/Zip:

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

Signature:

Print Name: Jacob Walczak

Firm: Natural Resource Technology, Inc.

Template: WELL DEVELOPMENT - Project: DUCK CREEK.GPJ

Date Modified: 5/14/2013

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL DEVELOPMENT

Facility/Project Name	State	Well Name
Ameren Duck Creek Energy Center	VA	GS4

Facility License, Permit or Monitoring Number

1. Can this well be purged dry? ☒ Yes ☐ No

2. Well development method:
   - surged with bailer and bailed ☒
   - surged with bailer and pumped ☐
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed, and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - other ______________________ ☐

3. Time spent developing well 60 min.

4. Depth of well (from top of well casing) 21.9 ft.

5. Inside diameter of well 2.07 in.

6. Volume of water in filter pack and well casing 7.7 gal.

7. Volume of water removed from well 7.5 gal.

8. Volume of water added (if any) 0.0 gal.

9. Source of water added not applicable

10. Analysis performed on water added? ☐ Yes ☒ No
    (If yes, attach results)

		Before Development	After Development
11. Depth to Water (from top of well casing)	a.	12.70 ft.	21.95 ft.
Date	b.	4/30/2013	4/30/2013
Time	c.	11:30 ☒ a.m. ☐ p.m.	02:35 ☐ a.m. ☒ p.m.
12. Sediment in well bottom		0.0 inches	0.0 inches
13. Water clarity		Clear ☐ Turbid ☒ (Describe) yellowish brown	Clear ☐ Turbid ☒ (Describe) yellowish brown

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	mg/l	mg/l
15. COD	mg/l	mg/l

16. Well developed by: Person's Name and Firm

Jacob Walczak

Natural Resource Technology, Inc.

17. Additional comments on development:

Surged with bailer for 20 minutes, then bailed dry twice.

Facility Address or Owner/Responsible Party Address

Name: _

Firm: Ameren

Street:

City/State/Zip:

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

Signature:

Print Name: Jacob Walczak

Firm: Natural Resource Technology, Inc.

Template: WELL DEVELOPMENT - Project: DUCK CREEK.GPJ

Date Modified: 5/14/2013

NATURAL
RESOURCE
TECHNOLOGY

MONITORING WELL DEVELOPMENT

Facility/Project Name	State	Well Name
Ameren Duck Creek Energy Center	VA	GS5

Facility License, Permit or Monitoring Number

1. Can this well be purged dry? ☐ Yes ☒ No

2. Well development method:
   - surged with bailer and bailed ☐
   - surged with bailer and pumped ☒
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed, and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - other ________ ☐

3. Time spent developing well 80 min.

4. Depth of well (from top of well casing) 27.0 ft.

5. Inside diameter of well 2.07 in.

6. Volume of water in filter pack and well casing 11.2 gal.

7. Volume of water removed from well 40.0 gal.

8. Volume of water added (if any) 0.0 gal.

9. Source of water added not applicable

10. Analysis performed on water added? ☐ Yes ☒ No
(If yes, attach results)

		Before Development	After Development
11. Depth to Water (from top of well casing)	a.	11.88 ft.	15.40 ft.
Date	b.	4/30/2013	4/30/2013
Time	c.	09:20 ☒ a.m. ☐ p.m.	10:40 ☒ a.m. ☐ p.m.
12. Sediment in well bottom		0.0 inches	0.0 inches
13. Water clarity		Clear ☐ Turbid ☒ (Describe) brown	Clear ☒ Turbid ☐ (Describe) cloudy brown

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	mg/l	mg/l
15. COD	mg/l	mg/l

16. Well developed by: Person's Name and Firm

Jacob Walczak

Natural Resource Technology, Inc.

17. Additional comments on development:

Surged with bailer for 20 minutes, then pumped.

Facility Address or Owner/Responsible Party Address

Name: _

Firm: Ameren

Street:

City/State/Zip:

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

Signature:

Print Name: Jacob Walczak

Firm: Natural Resource Technology, Inc.

Template: WELL DEVELOPMENT - Project: DUCK CREEK.GPJ

Date Modified: 5/14/2013

NATURAL
RESOURCE
TECHNOLOGY

MONITORING WELL DEVELOPMENT

Facility/Project Name	State	Well Name
Ameren Duck Creek Energy Center	VA	GS6

Facility License, Permit or Monitoring Number

1. Can this well be purged dry? ☒ Yes ☐ No

2. Well development method:
   - surged with bailer and bailed ☒
   - surged with bailer and pumped ☐
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed, and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - other ________ ☐

3. Time spent developing well 60 min.

4. Depth of well (from top of well casing) 22.6 ft.

5. Inside diameter of well 2.07 in.

6. Volume of water in filter pack and well casing 11 gal.

7. Volume of water removed from well 12.0 gal.

8. Volume of water added (if any) 0.0 gal.

9. Source of water added not applicable

10. Analysis performed on water added? ☐ Yes ☒ No
    (If yes, attach results)

		Before Development	After Development
11. Depth to Water (from top of well casing)	a.	7.75 ft.	15.35 ft.
Date	b.	4/29/2013	4/30/2013
Time	c.	04:25 ☐ a.m. ☒ p.m.	08:40 ☒ a.m. ☐ p.m.
12. Sediment in well bottom		0.0 inches	0.0 inches
13. Water clarity		Clear ☐ Turbid ☒ (Describe) cloudy tan	Clear ☒ Turbid ☐ (Describe) clear to cloudy tan

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	mg/l	mg/l
15. COD	mg/l	mg/l

16. Well developed by: Person's Name and Firm
Jacob Walczak
Natural Resource Technology, Inc.

17. Additional comments on development:
Surged with bailer for 20 minutes, then bailed dry twice.

Facility Address or Owner/Responsible Party Address

Name: _

Firm: Ameren

Street:

City/State/Zip:

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

Signature:

Print Name: Jacob Walczak

Firm: Natural Resource Technology, Inc.

Template: WELL DEVELOPMENT - Project: DUCK CREEK.GPJ

Date Modified: 5/14/2013

NATURAL RESOURCE TECHNOLOGY

MONITORING WELL DEVELOPMENT

Facility/Project Name: Ameren Duck Creek Energy Center

State: VA

Well Name: GS7

Facility License, Permit or Monitoring Number:

1. Can this well be purged dry? ☒ Yes ☐ No

2. Well development method:
   - surged with bailer and bailed ☐
   - surged with bailer and pumped ☒
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed, and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - other ______ ☐

3. Time spent developing well 60 min.

4. Depth of well (from top of well casing) 26.3 ft.

5. Inside diameter of well 2.07 in.

6. Volume of water in filter pack and well casing 12.6 gal.

7. Volume of water removed from well 26.0 gal.

8. Volume of water added (if any) 0.0 gal.

9. Source of water added not applicable

10. Analysis performed on water added? ☐ Yes ☒ No
(If yes, attach results)

		Before Development	After Development
11. Depth to Water (from top of well casing)	a.	4.72 ft.	5.02 ft.
Date	b.	4/29/2013	4/29/2013
Time	c.	12:51 ☐ a.m. ☒ p.m.	03:20 ☐ a.m. ☒ p.m.
12. Sediment in well bottom		0.0 inches	0.0 inches
13. Water clarity		Clear ☐ Turbid ☒ (Describe) light brown to tan	Clear ☐ Turbid ☒ (Describe) cloudy tan to very turbid tan

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	mg/l	mg/l
15. COD	mg/l	mg/l

16. Well developed by: Person's Name and Firm

Jacob Walczak

Natural Resource Technology, Inc.

17. Additional comments on development:

Surged with bailer for 20 minutes. Bailed well dry once. Pumped well dry twice.

Facility Address or Owner/Responsible Party Address

Name: _

Firm: Ameren

Street:

City/State/Zip:

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

Signature:

Print Name: Jacob Walczak

Firm: Natural Resource Technology, Inc.

Template: WELL DEVELOPMENT - Project: DUCK CREEK.GPJ

Date Modified: 5/14/2013

NATURAL
RESOURCE
TECHNOLOGY

MONITORING WELL DEVELOPMENT

Facility/Project Name: Ameren Duck Creek Energy Center

State: VA

Well Name: GS8

Facility License, Permit or Monitoring Number:

1. Can this well be purged dry? ☒ Yes ☐ No

2. Well development method:
   - surged with bailer and bailed ☐
   - surged with bailer and pumped ☒
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed, and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - other ______ ☐

3. Time spent developing well 60 min.

4. Depth of well (from top of well casing) 21.9 ft.

5. Inside diameter of well 2.07 in.

6. Volume of water in filter pack and well casing 5.6 gal.

7. Volume of water removed from well 9.0 gal.

8. Volume of water added (if any) 0.0 gal.

9. Source of water added not applicable

10. Analysis performed on water added? ☐ Yes ☒ No
    (If yes, attach results)

		Before Development	After Development
11. Depth to Water (from top of well casing)	a.	15.21 ft.	15.70 ft.
Date	b.	4/29/2013	4/30/2013
Time	c.	05:30 ☐ a.m. ☒ p.m.	08:20 ☒ a.m. ☐ p.m.
12. Sediment in well bottom		0.0 inches	0.0 inches
13. Water clarity		Clear ☐ Turbid ☒ (Describe) brown	Clear ☐ Turbid ☒ (Describe) cloudy tan to brown

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	mg/l	mg/l
15. COD	mg/l	mg/l

16. Well developed by: Person's Name and Firm

Jacob Walczak

Natural Resource Technology, Inc.

17. Additional comments on development:

Surged with bailer for 20 minutes. Bailed well dry once. Pumped well dry once.

Facility Address or Owner/Responsible Party Address

Name: _

Firm: Ameren

Street:

City/State/Zip:

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

Signature:

Print Name: Jacob Walczak

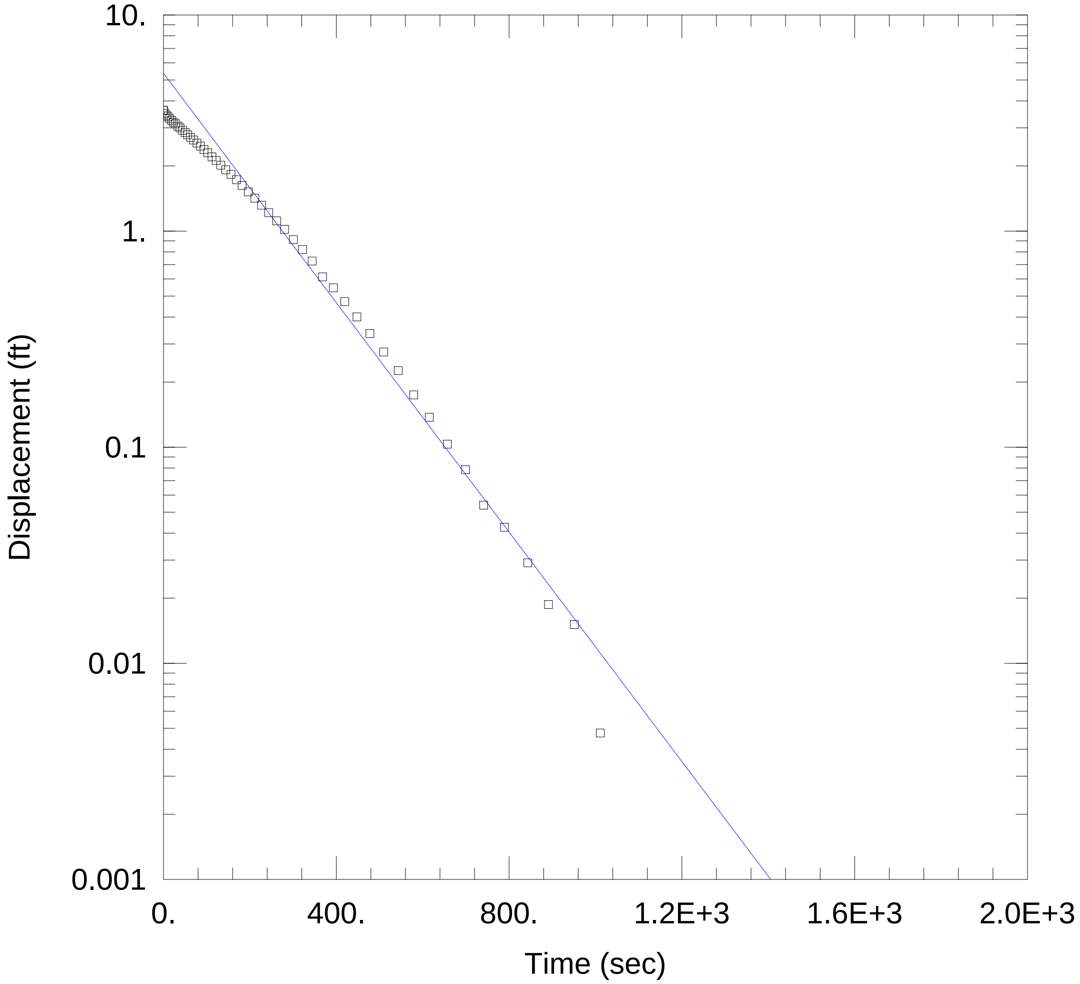
Firm: Natural Resource Technology, Inc.

Template: WELL DEVELOPMENT - Project: DUCK CREEK.GPJ

Date Modified: 5/14/2013

Attachment C

Slug Test Data and Plots



WELL TEST ANALYSIS

Data Set: P:\...\GS1SlugOut1.aqt
Date: 07/03/13 Time: 15:25:20

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS1
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 13.6 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS1 Slug Out 1)

Initial Displacement: 3.62 ft
Static Water Column Height: 13.6 ft
Total Well Penetration Depth: 13.6 ft
Screen Length: 10. ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.000237 cm/sec
y0 = 5.371 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS1SlugOut1.ac
Date: 07/03/13
Time: 15:25:29

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS1

AQUIFER DATA

Saturated Thickness: 13.6 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS1 Slug Out 1

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 3.62 ft
Static Water Column Height: 13.6 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 10. ft
Total Well Penetration Depth: 13.6 ft

No. of Observations: 52

Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	3.615	196.6	1.518
3.36	3.508	211.6	1.419
6.96	3.432	227.2	1.316
10.56	3.375	244.	1.216
14.76	3.31	262.	1.115
18.96	3.245	280.6	1.019
23.16	3.179	301.	0.9133
27.96	3.131	322.	0.8213
33.36	3.055	344.2	0.7269
38.16	3.	368.2	0.6135
44.16	2.927	393.4	0.5466
50.16	2.859	419.8	0.4716
56.16	2.788	448.	0.4003
62.76	2.712	478.	0.3355
69.96	2.636	509.8	0.2755
77.76	2.552	543.4	0.2263
85.56	2.47	579.4	0.1745
93.96	2.384	615.4	0.1374
103.	2.3	657.4	0.1032
112.6	2.205	699.4	0.07875
122.2	2.119	741.4	0.05388
133.	2.018	789.4	0.04261
144.4	1.921	843.4	0.02915
156.4	1.827	891.4	0.0187
169.	1.726	951.4	0.01511
182.2	1.623	1011.4	0.004758

SOLUTION

Slug Test

AQTESOLV for Windows

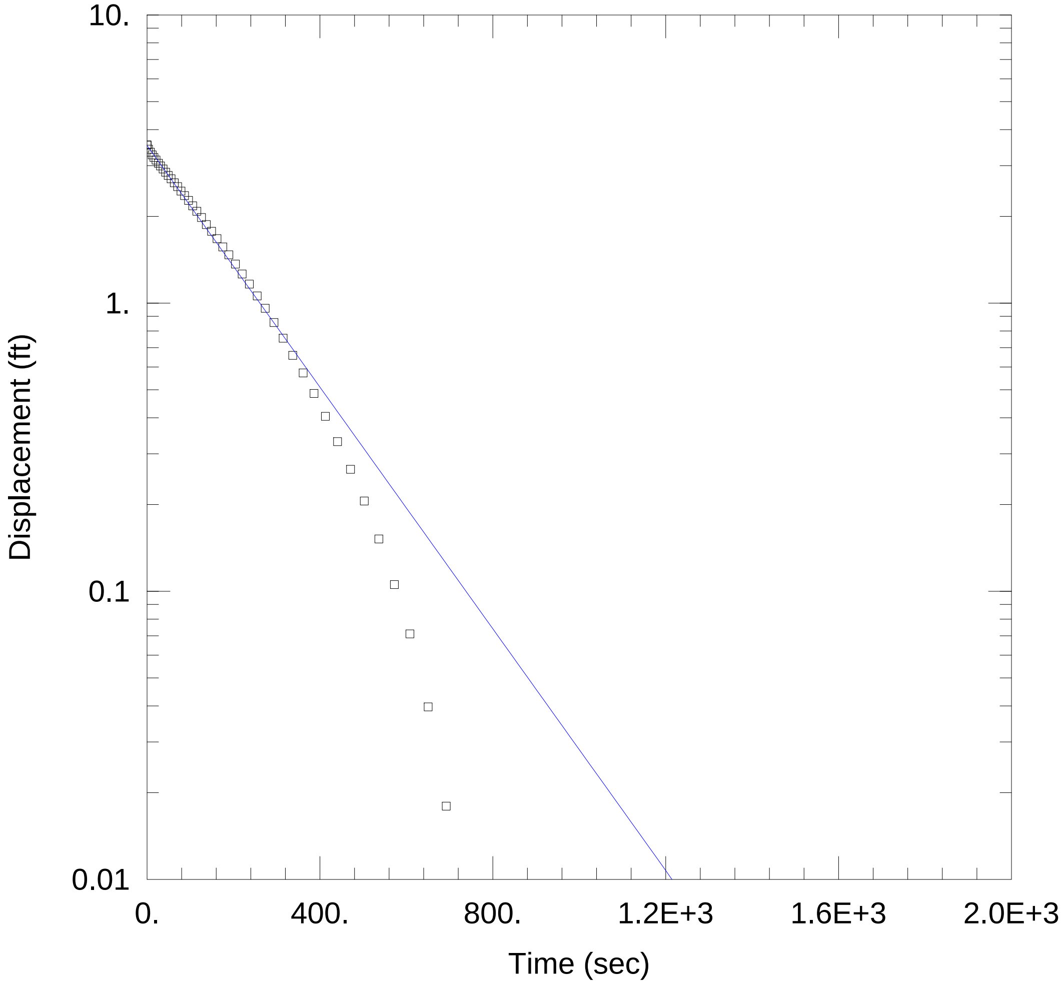
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 3.891

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
K	0.000237	cm/sec
y0	5.371	ft

T = K*b = 0.09823 cm^2/sec



WELL TEST ANALYSIS

Data Set: P:\...\GS1SlugOut2.aqt
Date: 07/03/13
Time: 15:25:34

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS1
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 13.62 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS1 Slug Out 2)

Initial Displacement: 3.54 ft
Static Water Column Height: 13.62 ft
Total Well Penetration Depth: 13.62 ft
Screen Length: 10. ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.0001872 cm/sec
y0 = 3.522 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS1SlugOut2.ac
Date: 07/03/13
Time: 15:25:38

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS1

AQUIFER DATA

Saturated Thickness: 13.62 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS1 Slug Out 2

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 3.54 ft
Static Water Column Height: 13.62 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 10. ft
Total Well Penetration Depth: 13.62 ft

No. of Observations: 51

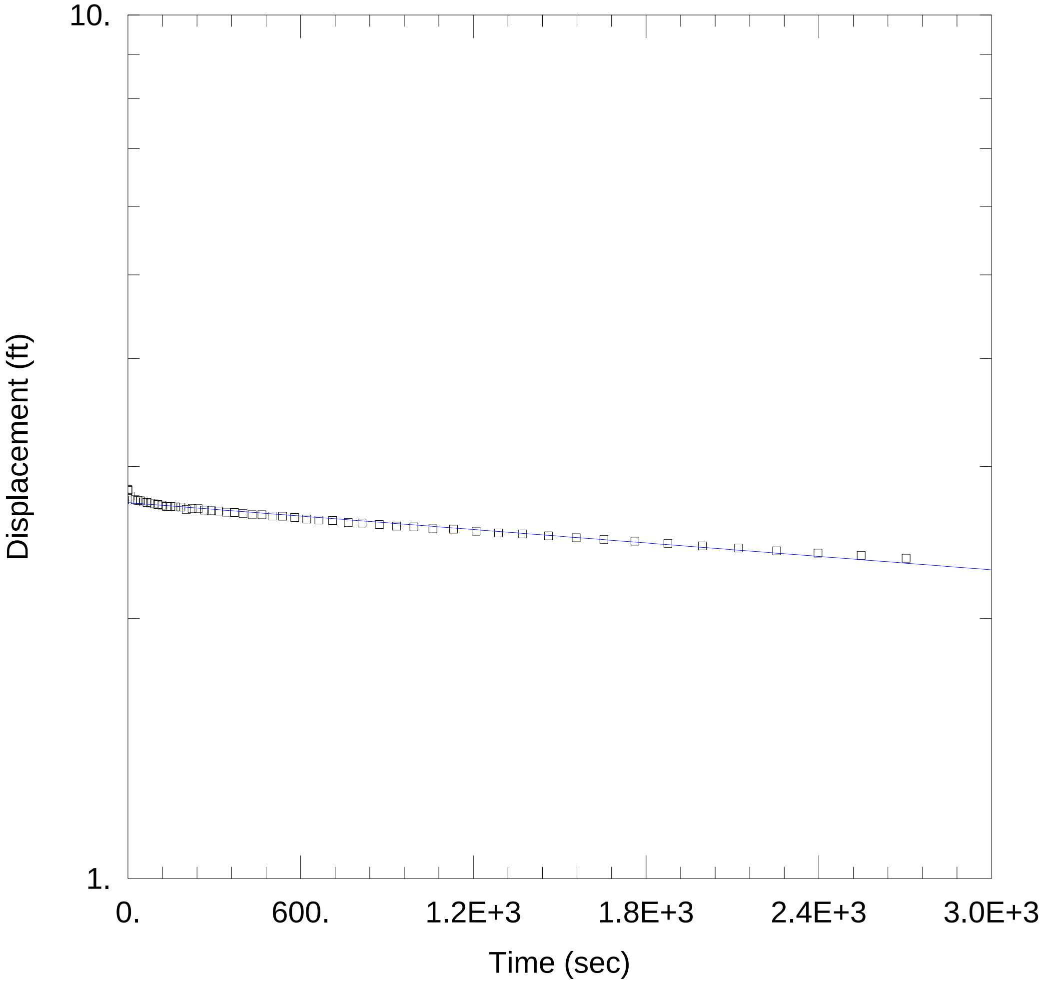
Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	3.531	220.2	1.261
3.6	3.423	237.	1.164
7.801	3.339	255.	1.059
12.	3.266	273.6	0.9594
16.2	3.202	294.	0.8556
21.	3.136	315.	0.7547
26.4	3.056	337.2	0.6583
31.2	2.99	361.2	0.5724
37.2	2.917	386.4	0.4858
43.2	2.846	412.8	0.4046
49.2	2.773	441.	0.3306
55.8	2.701	471.	0.2649
63.	2.615	502.8	0.2055
70.8	2.536	536.4	0.1519
78.6	2.446	572.4	0.1054
87.	2.361	608.4	0.07109
96.	2.271	650.4	0.03966
105.6	2.174	692.4	0.01795
115.2	2.082	734.4	-0.003047
126.	1.982	782.4	-0.008226
137.4	1.872	836.4	-0.02085
149.4	1.776	884.4	-0.02923
162.	1.674	944.4	-0.03467
175.2	1.566	1004.4	-0.04171
189.6	1.47	1064.4	-0.05129
204.6	1.365		

SOLUTION

Slug Test

```
AQTESOLV for Windows
________________________________________________________________________

Aquifer Model:  Unconfined
Solution Method:  Bouwer-Rice
ln(Re/rw):  3.892
________________________________________________________________________

VISUAL ESTIMATION RESULTS

Estimated Parameters

    Parameter        Estimate
        K           0.0001872    cm/sec
        y0            3.522      ft

T = K*b = 0.07773 cm²/sec
________________________________________________________________________

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

    Parameter        Estimate       Std. Error      Approx. C.I.       t-Ratio
        K           0.0001872        2.688E-6      +/- 5.403E-6         69.66     cm/sec
        y0            3.522          0.02275       +/- 0.04573          154.8     ft

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 0.07773 cm²/sec

Parameter Correlations

           K        y0
     K   1.00      0.65
    y0   0.65      1.00

Residual Statistics

      for weighted residuals

      Sum of Squares . . . . . . 0.2144 ft²
      Variance . . . . . . . . . . . . 0.004375 ft²
      Std. Deviation . . . . . . . . 0.06615 ft
      Mean . . . . . . . . . . . . . . . -0.02237 ft
      No. of Residuals . . . . . . 51
      No. of Estimates . . . . . . 2
```



WELL TEST ANALYSIS

Data Set: P:\...\GS2 SlugOut1.aqt
Date: 07/03/13
Time: 15:25:53

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS2
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 11.62 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS2 Slug Out 1)

Initial Displacement: 2.82 ft
Static Water Column Height: 11.62 ft
Total Well Penetration Depth: 11.62 ft
Screen Length: 10. ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 2.257E-6 cm/sec
y0 = 2.724 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS2 SlugOut1.a
Date: 07/03/13
Time: 15:25:58

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS2

AQUIFER DATA

Saturated Thickness: 11.62 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS2 Slug Out 1

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 2.82 ft
Static Water Column Height: 11.62 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 10. ft
Total Well Penetration Depth: 11.62 ft

No. of Observations: 54

Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	2.814	501.6	2.629
7.801	2.772	537.6	2.627
16.2	2.743	579.6	2.618
25.2	2.745	621.6	2.608
34.8	2.74	663.6	2.601
44.4	2.738	711.6	2.597
55.2	2.729	765.6	2.583
66.6	2.725	813.6	2.58
78.6	2.721	873.6	2.57
91.2	2.715	933.6	2.559
104.4	2.711	993.6	2.554
118.8	2.706	1059.6	2.54
133.9	2.697	1131.6	2.538
149.4	2.697	1209.6	2.524
166.2	2.693	1287.6	2.513
184.2	2.692	1371.6	2.506
202.8	2.674	1461.6	2.493
223.2	2.681	1557.6	2.48
244.2	2.681	1653.6	2.47
266.4	2.671	1761.6	2.458
290.4	2.666	1875.6	2.443
315.6	2.664	1995.6	2.428
342.	2.656	2121.6	2.414
370.2	2.654	2253.6	2.395
400.2	2.646	2397.6	2.381
432.	2.637	2547.6	2.367
465.6	2.638	2703.6	2.349

SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 3.79

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
K	2.257E-6	cm/sec
y0	2.724	ft

T = K*b = 0.0007992 cm²/sec

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	Std. Error	Approx. C.I.	t-Ratio	
K	2.257E-6	5.487E-8	+/- 1.101E-7	41.13	cm/sec
y0	2.724	0.003957	+/- 0.007942	688.4	ft

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 0.0007992 cm²/sec

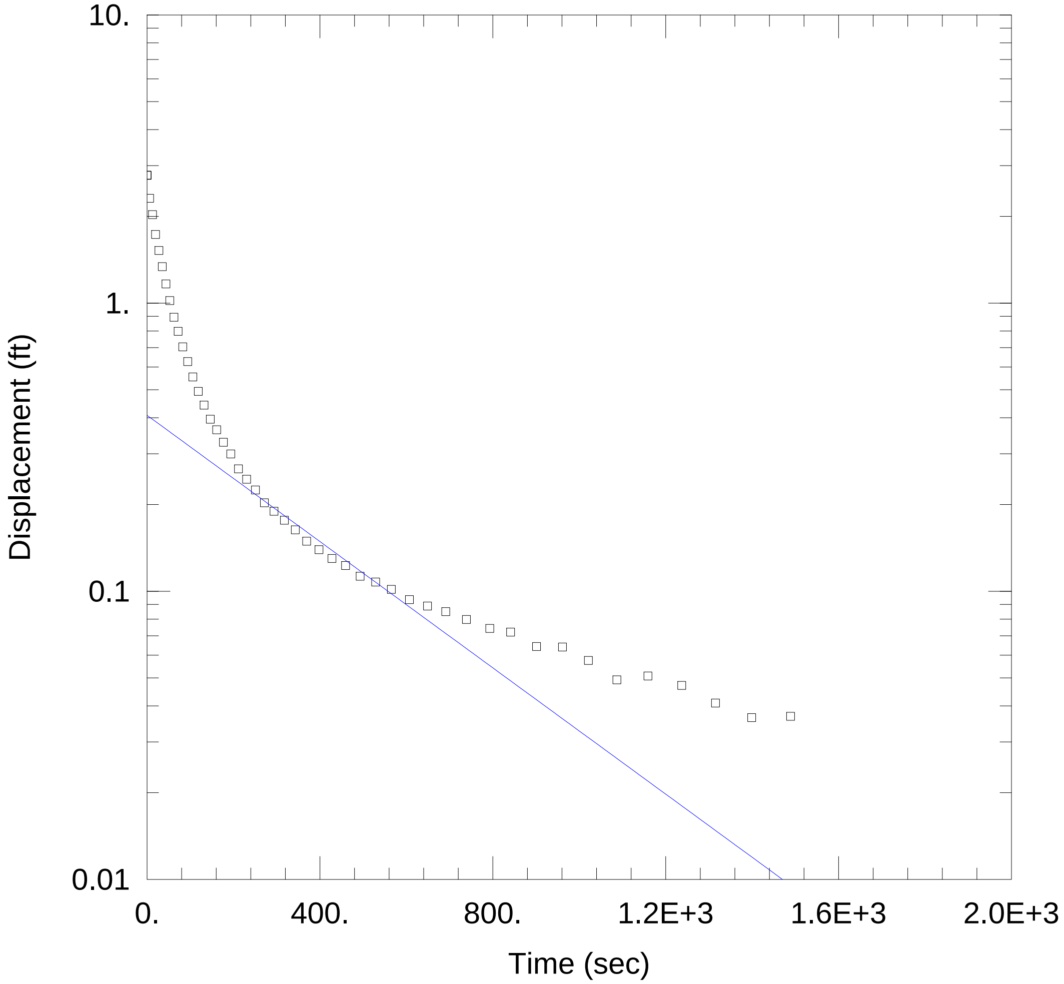
Parameter Correlations

	K	y0
K	1.00	0.70
y0	0.70	1.00

Residual Statistics

for weighted residuals

Sum of Squares . . . . . . 0.02062 ft^2
Variance . . . . 0.0003966 ft^2
Std. Deviation . . . . 0.01991 ft
Mean . . . . 0.0008222 ft
No. of Residuals 54
No. of Estimates 2



WELL TEST ANALYSIS

Data Set: P:\...\GS3 SlugOut1.aqt
Date: 07/03/13 Time: 15:26:03

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS3
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 15.63 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS3 Slug Out 1)

Initial Displacement: 2.78 ft
Static Water Column Height: 15.63 ft
Total Well Penetration Depth: 15.63 ft
Screen Length: 10. ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.000653 cm/sec
y0 = 0.4079 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS3 SlugOut1.a
Date: 07/03/13
Time: 15:26:08

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS3

AQUIFER DATA

Saturated Thickness: 15.63 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS3 Slug Out 1

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 2.78 ft
Static Water Column Height: 15.63 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 10. ft
Total Well Penetration Depth: 15.63 ft

No. of Observations: 48

Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.	2.774	318.	0.1765
6.	2.309	343.2	0.1634
12.6	2.028	369.6	0.1491
19.8	1.73	397.8	0.1394
27.6	1.523	427.8	0.13
35.4	1.338	459.6	0.1228
43.8	1.165	493.2	0.1127
52.8	1.02	529.2	0.1077
62.4	0.8929	565.2	0.1015
72.	0.7977	607.2	0.09355
82.8	0.7046	649.2	0.08882
94.2	0.6264	691.2	0.08495
106.2	0.5542	739.2	0.07976
118.8	0.4937	793.2	0.07432
132.	0.4425	841.2	0.07214
146.4	0.3953	901.2	0.06426
161.4	0.3635	961.2	0.06401
177.	0.3287	1021.2	0.05749
193.8	0.2997	1087.2	0.04927
211.8	0.2658	1159.2	0.05083
230.5	0.2445	1237.2	0.04708
250.8	0.2246	1315.2	0.0409
271.8	0.2027	1399.2	0.03642
294.	0.1894	1489.2	0.03679

SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

ln(Re/rw): 25.98

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
K	0.000653	cm/sec
y0	0.4079	ft

T = K*b = 0.3111 cm²/sec

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	Std. Error	Approx. C.I.	t-Ratio	
K	0.003768	0.0001903	+/- 0.0003832	19.8	cm/sec
y0	2.46	0.06838	+/- 0.1376	35.98	ft

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 1.795 cm²/sec

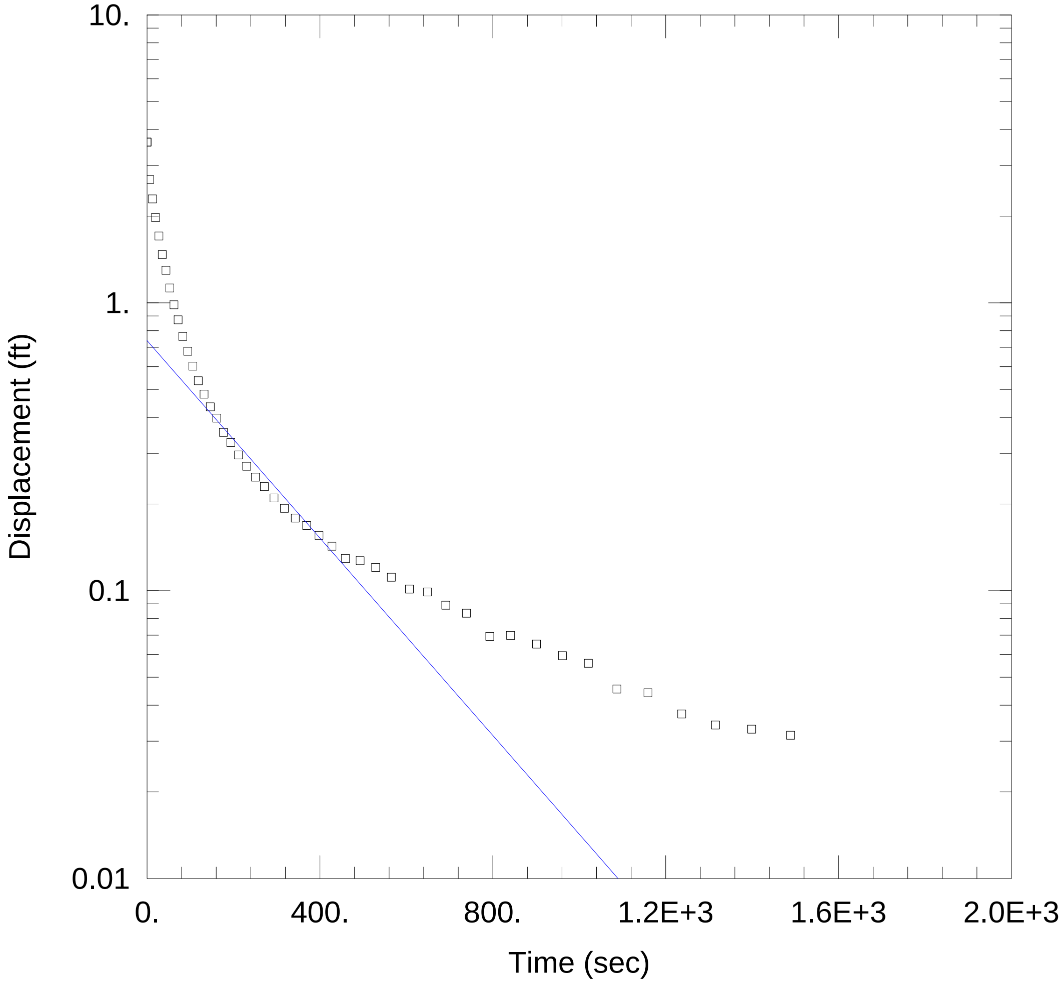
Parameter Correlations

	K	y0
K	1.00	0.66
y0	0.66	1.00

Residual Statistics

for weighted residuals

Sum of Squares . . . . . . 0.6088 ft^2
Variance . . . . 0.01323 ft^2
Std. Deviation . . . . 0.115 ft
Mean . . . . 0.06418 ft
No. of Residuals 48
No. of Estimates 2



WELL TEST ANALYSIS

Data Set: P:\...\GS3 SlugOut2.aqt
Date: 07/03/13 Time: 15:26:12

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS3
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 15.61 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS3 Slug Out 2)

Initial Displacement: 3.62 ft
Static Water Column Height: 15.61 ft
Total Well Penetration Depth: 15.61 ft
Screen Length: 10. ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.0001566 cm/sec
y0 = 0.7386 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS3 SlugOut2.a
Date: 07/03/13
Time: 15:26:16

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS3

AQUIFER DATA

Saturated Thickness: 15.61 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS3 Slug Out 2

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 3.62 ft
Static Water Column Height: 15.61 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 10. ft
Total Well Penetration Depth: 15.61 ft

No. of Observations: 48

Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	3.61	318.	0.1931
6.	2.68	343.2	0.1785
12.6	2.294	369.6	0.1684
19.8	1.976	397.8	0.1556
27.6	1.705	427.8	0.1427
35.4	1.47	459.6	0.1292
43.8	1.296	493.2	0.1272
52.8	1.126	529.2	0.1203
62.4	0.9836	565.2	0.1113
72.	0.8725	607.2	0.1012
82.8	0.7639	649.2	0.09886
94.2	0.6784	691.2	0.08893
106.2	0.6023	739.2	0.08349
118.8	0.5358	793.2	0.06934
132.	0.4813	841.2	0.06981
146.4	0.4349	901.2	0.06522
161.4	0.3974	961.2	0.05942
177.	0.3544	1021.2	0.05592
193.8	0.3272	1087.2	0.0455
211.8	0.296	1159.2	0.04417
230.4	0.2703	1237.2	0.03726
250.8	0.2479	1315.2	0.03412
271.8	0.2297	1399.2	0.03302
294.	0.2098	1489.2	0.03144

SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

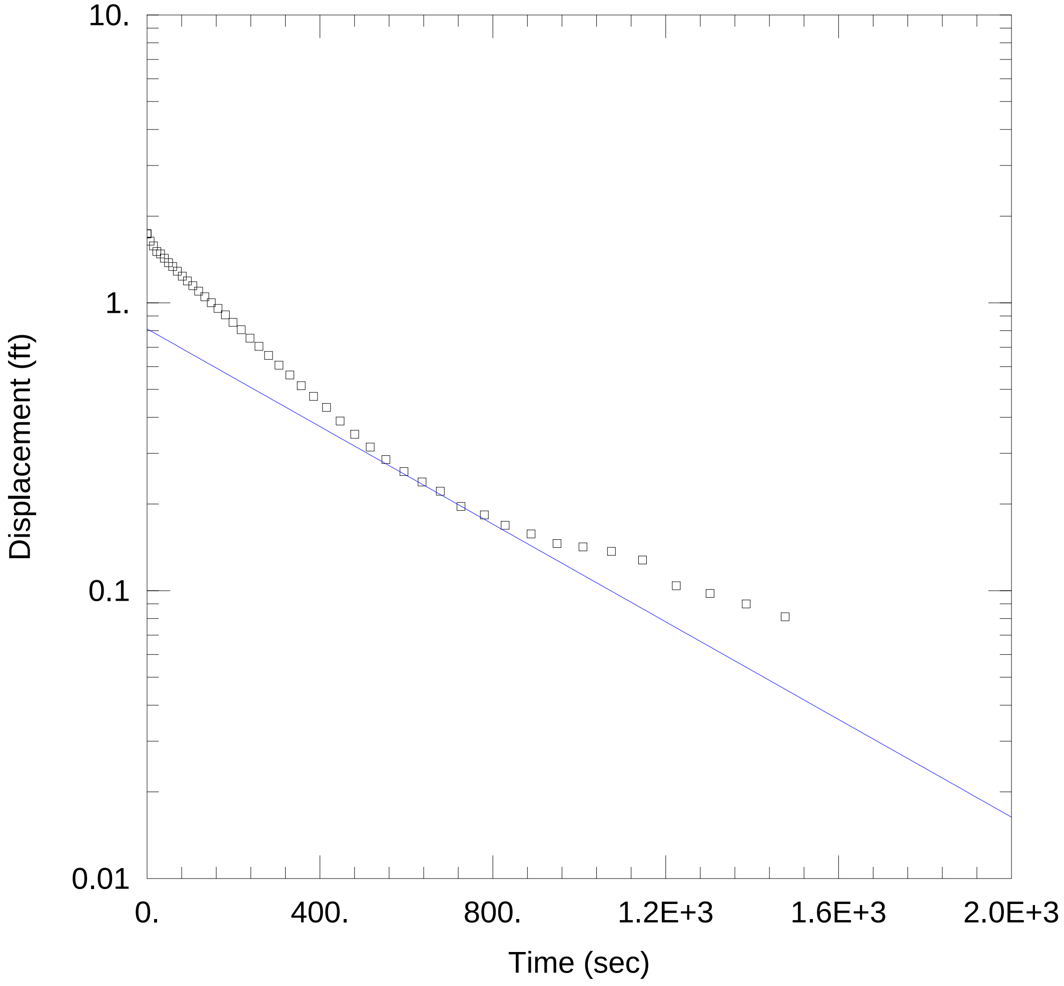
ln(Re/rw): 3.979

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
K	0.0001566	cm/sec
y0	0.7386	ft

T = K*b = 0.07449 cm²/sec



WELL TEST ANALYSIS

Data Set: P:\...\GS4 SlugOut1.aqt
Date: 07/03/13 Time: 15:26:21

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS4
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 8.68 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS4 Slug Out 1)

Initial Displacement: 1.74 ft
Static Water Column Height: 8.68 ft
Total Well Penetration Depth: 8.68 ft
Screen Length: 8.68 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 8.019E-5 cm/sec
y0 = 0.8114 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS4 SlugOut1.a
Date: 07/03/13
Time: 15:26:26

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS4

AQUIFER DATA

Saturated Thickness: 8.68 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS4 Slug Out 1

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 1.74 ft
Static Water Column Height: 8.68 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 8.68 ft
Total Well Penetration Depth: 8.68 ft

No. of Observations: 46

Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	1.734	330.6	0.5611
7.201	1.638	357.	0.5153
15.	1.576	385.2	0.4728
22.8	1.506	415.2	0.4328
31.2	1.479	447.	0.3885
40.2	1.427	480.6	0.3492
49.8	1.378	516.6	0.3153
59.4	1.335	552.6	0.2854
70.2	1.287	594.6	0.2592
81.6	1.238	636.6	0.2386
93.6	1.19	678.6	0.2216
106.2	1.145	726.6	0.196
119.4	1.097	780.6	0.1833
133.8	1.05	828.6	0.1687
148.8	1.001	888.6	0.1573
164.4	0.9552	948.6	0.1458
181.2	0.9081	1008.6	0.1419
199.2	0.8548	1074.6	0.137
217.8	0.8061	1146.6	0.1278
238.2	0.753	1224.6	0.104
259.2	0.706	1302.6	0.09784
281.4	0.6563	1386.6	0.08985
305.4	0.607	1476.6	0.08113

SOLUTION

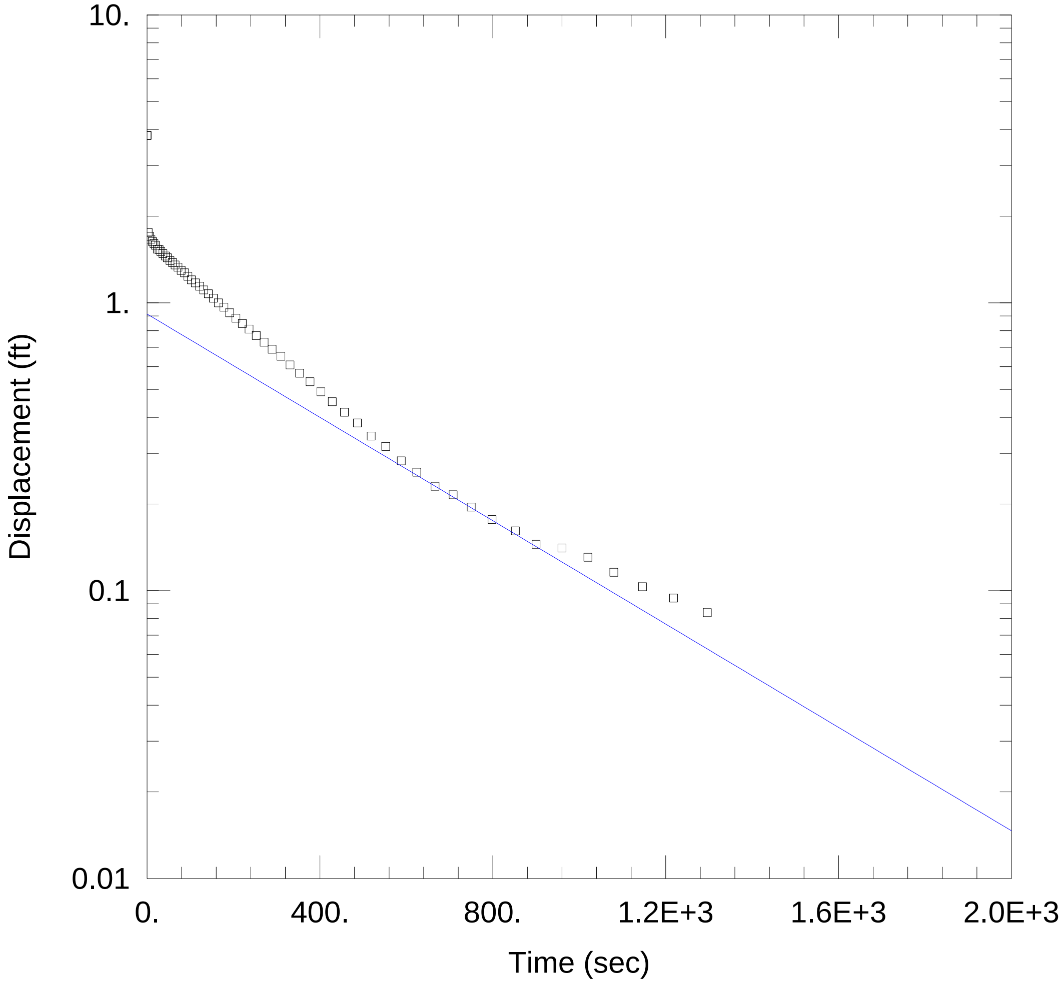
Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 3.577

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
K	8.019E-5	cm/sec
y0	0.8114	ft

T = K*b = 0.02122 cm²/sec



WELL TEST ANALYSIS

Data Set: P:\...\GS4 SlugOut2.aqt
Date: 07/03/13
Time: 15:26:30

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS4
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 8.61 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS4 Slug Out 2)

Initial Displacement: 3.82 ft
Static Water Column Height: 8.61 ft
Total Well Penetration Depth: 8.61 ft
Screen Length: 8.61 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 8.543E-5 cm/sec
y0 = 0.9143 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS4 SlugOut2.a
Date: 07/03/13
Time: 15:26:33

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS4

AQUIFER DATA

Saturated Thickness: 8.61 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS4 Slug Out 2

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 3.82 ft
Static Water Column Height: 8.61 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 8.61 ft
Total Well Penetration Depth: 8.61 ft

No. of Observations: 59

Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	3.81	220.6	0.8476
2.82	1.754	236.2	0.8103
5.82	1.702	253.	0.7698
9.	1.663	271.	0.7292
12.36	1.634	289.6	0.6897
15.96	1.606	310.	0.6515
19.56	1.583	331.	0.6087
23.76	1.537	353.2	0.5694
27.96	1.533	377.2	0.5318
32.16	1.507	402.4	0.4908
36.96	1.482	428.8	0.4535
42.36	1.453	457.	0.4166
47.16	1.434	487.	0.3826
53.16	1.402	518.8	0.3441
59.16	1.38	552.4	0.3168
65.16	1.354	588.4	0.2825
71.76	1.329	624.4	0.2579
78.96	1.296	666.4	0.2304
86.76	1.271	708.4	0.2154
94.56	1.236	750.4	0.1952
103.	1.202	798.4	0.1767
112.	1.173	852.4	0.1612
121.6	1.141	900.4	0.1449
131.2	1.109	960.4	0.1406
142.	1.075	1020.4	0.1306
153.4	1.037	1080.4	0.1158
165.4	0.9999	1146.4	0.1032
178.	0.965	1218.4	0.09425
191.2	0.9233	1296.4	0.08384
205.6	0.8838		

SOLUTION

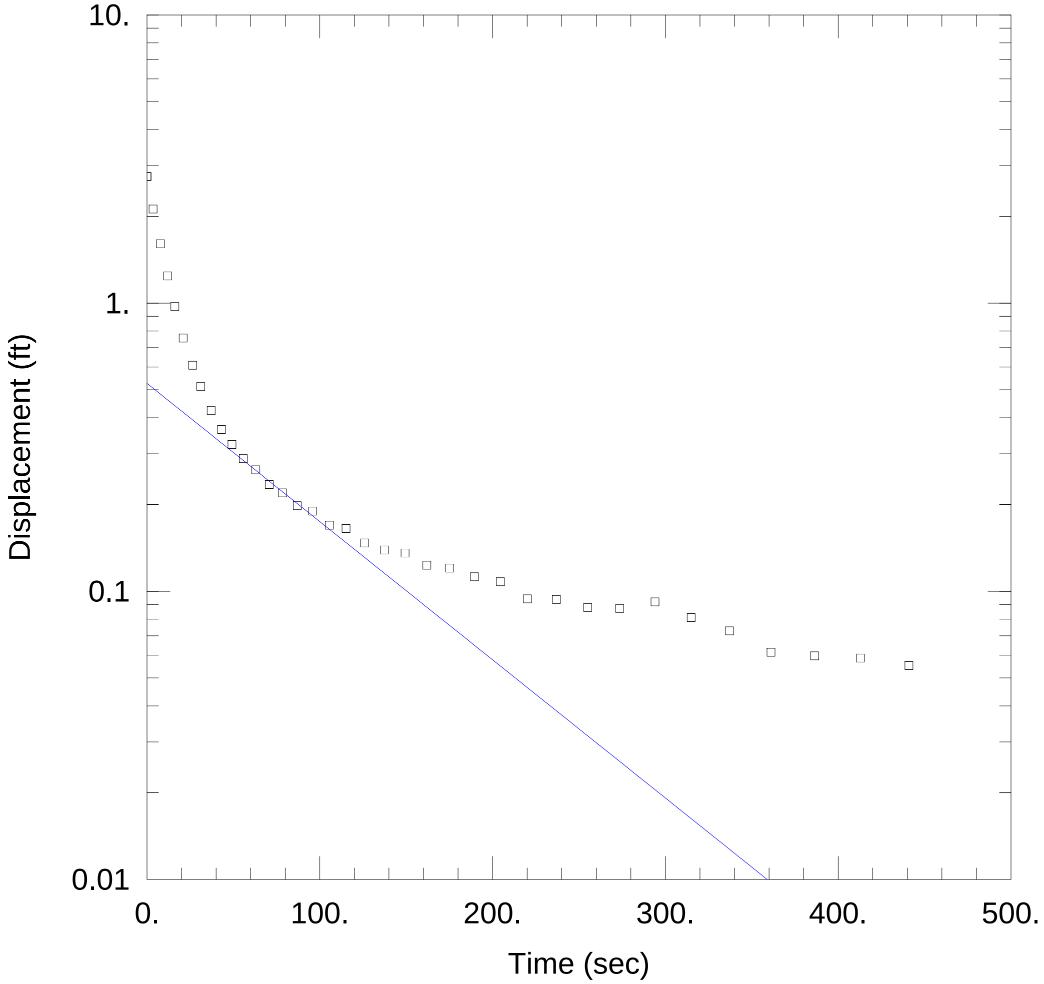
Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 3.571

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
K	8.543E-5	cm/sec
y0	0.9143	ft

T = K*b = 0.02242 cm²/sec



WELL TEST ANALYSIS

Data Set: P:\...\GS5 SlugOut1.aqt
Date: 07/03/13
Time: 15:26:37

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS5
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 14.35 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS5 Slug Out 1)

Initial Displacement: 2.75 ft
Static Water Column Height: 14.35 ft
Total Well Penetration Depth: 14.35 ft
Screen Length: 10. ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.000432 cm/sec
y0 = 0.5263 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS5 SlugOut1.a
Date: 07/03/13
Time: 15:26:42

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS5

AQUIFER DATA

Saturated Thickness: 14.35 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS5 Slug Out 1

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 2.75 ft
Static Water Column Height: 14.35 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 10. ft
Total Well Penetration Depth: 14.35 ft

No. of Observations: 37

Observation Data

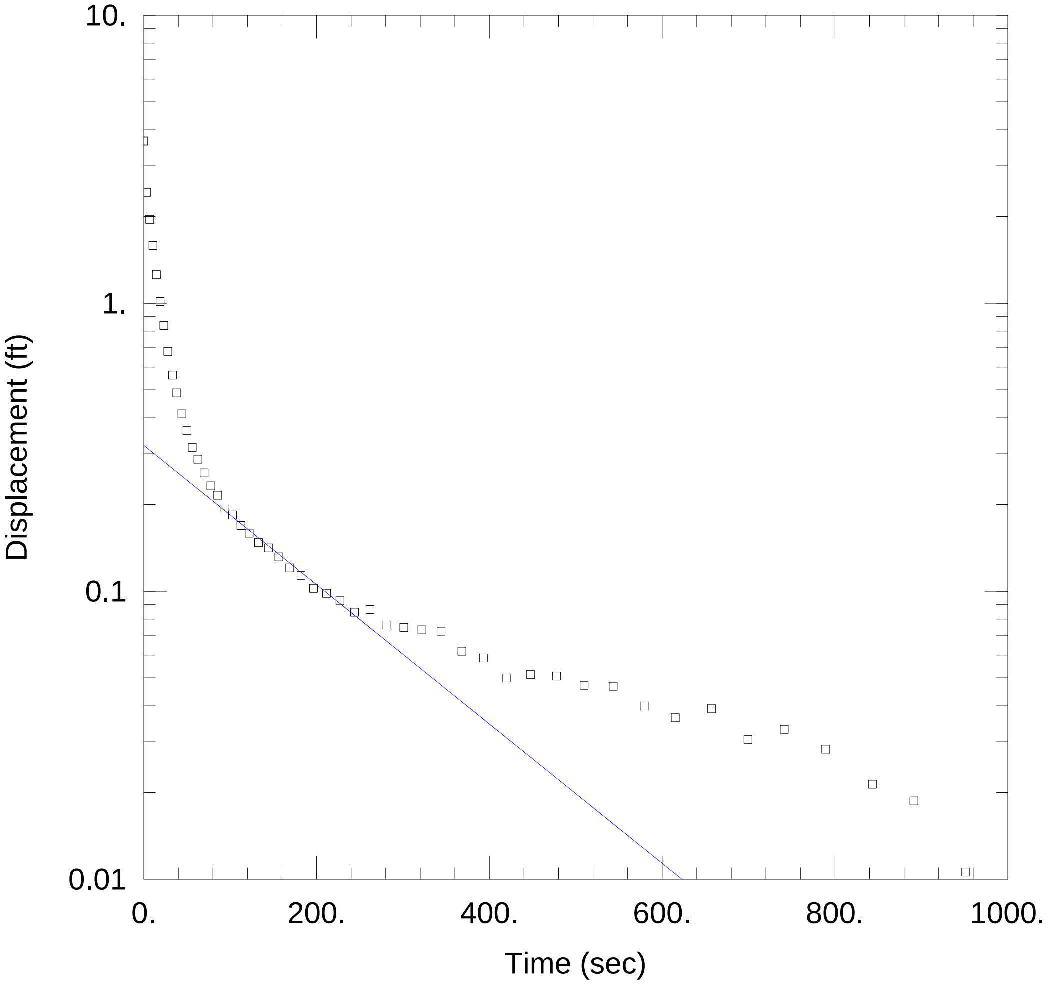
Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	2.749	126.	0.1471
3.599	2.12	137.4	0.1391
7.8	1.607	149.4	0.1357
12.	1.242	162.	0.1231
16.2	0.9726	175.2	0.1203
21.	0.7561	189.6	0.1123
26.4	0.6084	204.6	0.1079
31.2	0.5131	220.2	0.09405
37.2	0.4235	237.	0.09368
43.2	0.3644	255.	0.08788
49.2	0.3229	273.6	0.08712
55.8	0.2886	294.	0.09188
63.	0.2638	315.	0.08107
70.8	0.2345	337.2	0.07282
78.6	0.2194	361.2	0.06139
87.	0.1982	386.4	0.0597
96.	0.1897	412.8	0.05863
105.6	0.1696	441.	0.05523
115.2	0.1651		

SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 3.926

VISUAL ESTIMATION RESULTS

Estimated Parameters



WELL TEST ANALYSIS

Data Set: P:\...\GS5 SlugOut2.aqt
Date: 07/03/13 Time: 15:26:46

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS5
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 14.31 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS5 Slug Out 2)

Initial Displacement: 3.66 ft
Total Well Penetration Depth: 14.31 ft
Casing Radius: 0.0833 ft
Static Water Column Height: 14.31 ft
Screen Length: 10. ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.001318 cm/sec
y0 = 0.3209 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS5 SlugOut2.a
Date: 07/03/13
Time: 15:26:49

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS5

AQUIFER DATA

Saturated Thickness: 14.31 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS5 Slug Out 2

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 3.66 ft
Static Water Column Height: 14.31 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 10. ft
Total Well Penetration Depth: 14.31 ft

No. of Observations: 51

Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	3.653	196.6	0.1023
3.36	2.426	211.6	0.09825
6.961	1.953	227.2	0.0927
10.56	1.585	244.	0.08456
14.76	1.257	262.	0.08638
18.96	1.013	280.6	0.07632
23.16	0.8365	301.	0.07475
27.96	0.6801	322.	0.07343
33.36	0.563	344.2	0.07256
38.16	0.4882	368.2	0.06189
44.16	0.4127	393.4	0.0586
50.16	0.361	419.8	0.04999
56.16	0.3156	448.	0.05132
62.76	0.2871	478.	0.05073
69.96	0.2577	509.8	0.04709
77.76	0.2321	543.4	0.04672
85.56	0.2152	579.4	0.03992
93.96	0.1929	615.4	0.03639
103.	0.184	657.4	0.03906
112.6	0.169	699.4	0.03057
122.2	0.1589	741.4	0.03313
133.	0.1474	789.4	0.02826
144.4	0.1413	843.4	0.02136
156.4	0.1315	891.4	0.01871
169.	0.1205	951.4	0.01058
182.2	0.1134		

SOLUTION

Slug Test

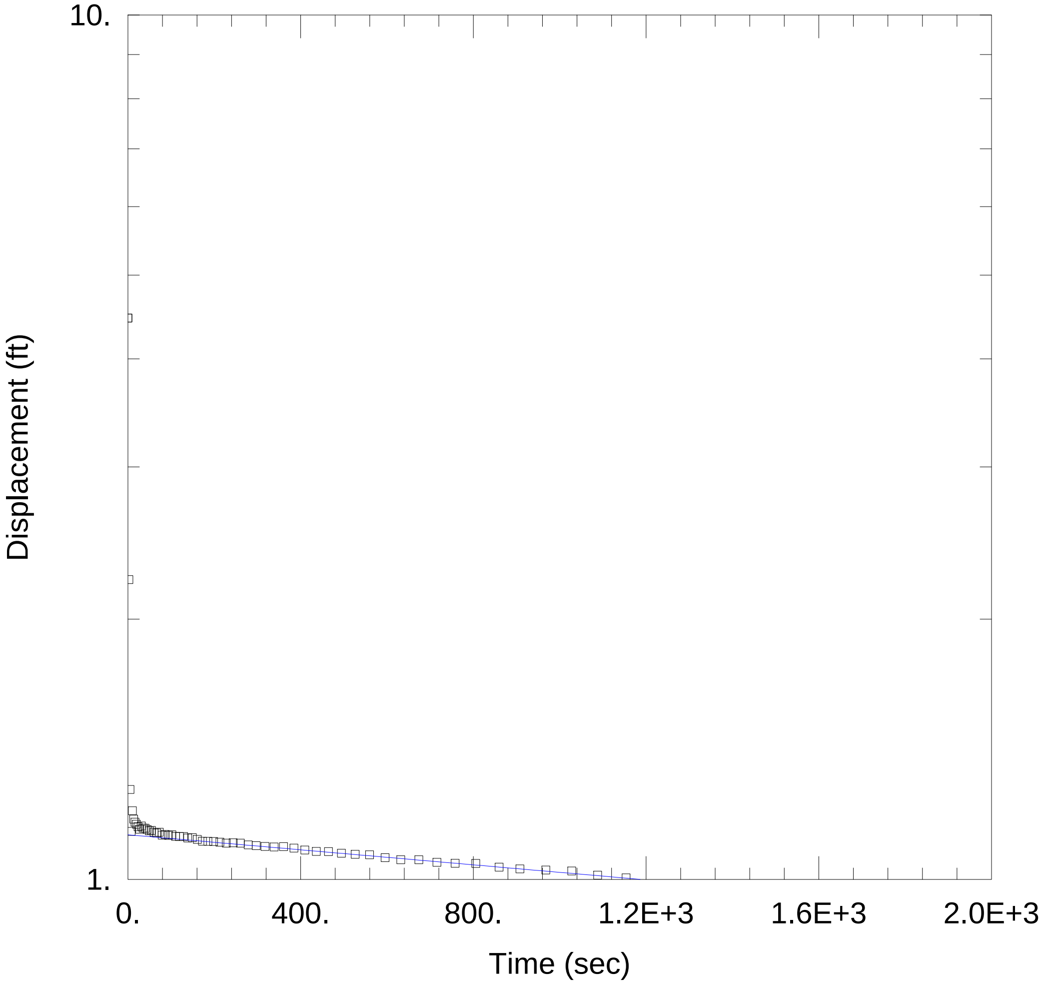
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 23.75

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
K	0.001318	cm/sec
y0	0.3209	ft

T = K*b = 0.575 cm^2/sec



WELL TEST ANALYSIS

Data Set: P:\...\GS6 SlugOut1.aqt
Date: 07/03/13
Time: 15:26:53

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS6
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 11.04 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS6 Slug Out 1)

Initial Displacement: 4.46 ft
Static Water Column Height: 11.04 ft
Total Well Penetration Depth: 11.04 ft
Screen Length: 10. ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 3.748E-6 cm/sec
y0 = 1.126 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS6 SlugOut1.a
Date: 07/03/13
Time: 15:27:02

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS6

AQUIFER DATA

Saturated Thickness: 11.04 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS6 Slug Out 1

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 4.46 ft
Static Water Column Height: 11.04 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 10. ft
Total Well Penetration Depth: 11.04 ft

No. of Observations: 60

Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	4.459	185.5	1.107
2.4	2.222	198.7	1.106
4.92	1.27	213.1	1.104
7.56	1.136	228.1	1.101
10.38	1.201	243.7	1.102
13.38	1.174	260.5	1.101
16.56	1.165	278.5	1.096
19.92	1.158	297.1	1.094
23.52	1.15	317.5	1.091
27.12	1.143	338.5	1.09
31.32	1.153	360.7	1.091
35.52	1.146	384.7	1.087
39.72	1.146	409.9	1.081
44.52	1.142	436.3	1.077
49.92	1.138	464.5	1.077
54.72	1.139	494.5	1.072
60.72	1.134	526.3	1.069
66.72	1.131	559.9	1.068
72.72	1.134	595.9	1.06
79.36	1.125	631.9	1.054
86.52	1.127	673.9	1.053
94.32	1.124	715.9	1.047
102.1	1.126	757.9	1.044
110.5	1.121	805.9	1.044
119.5	1.121	859.9	1.033
129.1	1.121	907.9	1.028
138.7	1.116	967.9	1.025
149.5	1.118	1027.9	1.023
160.9	1.112	1087.9	1.011
172.9	1.107	1153.9	1.004

SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 3.757

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
K	3.748E-6	cm/sec
y0	1.126	ft

T = K*b = 0.001261 cm²/sec

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	Std. Error	Approx. C.I.	t-Ratio	
K	1.319E-5	6.581E-6	+/- 1.317E-5	2.004	cm/sec
y0	1.304	0.08424	+/- 0.1687	15.48	ft

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 0.004437 cm²/sec

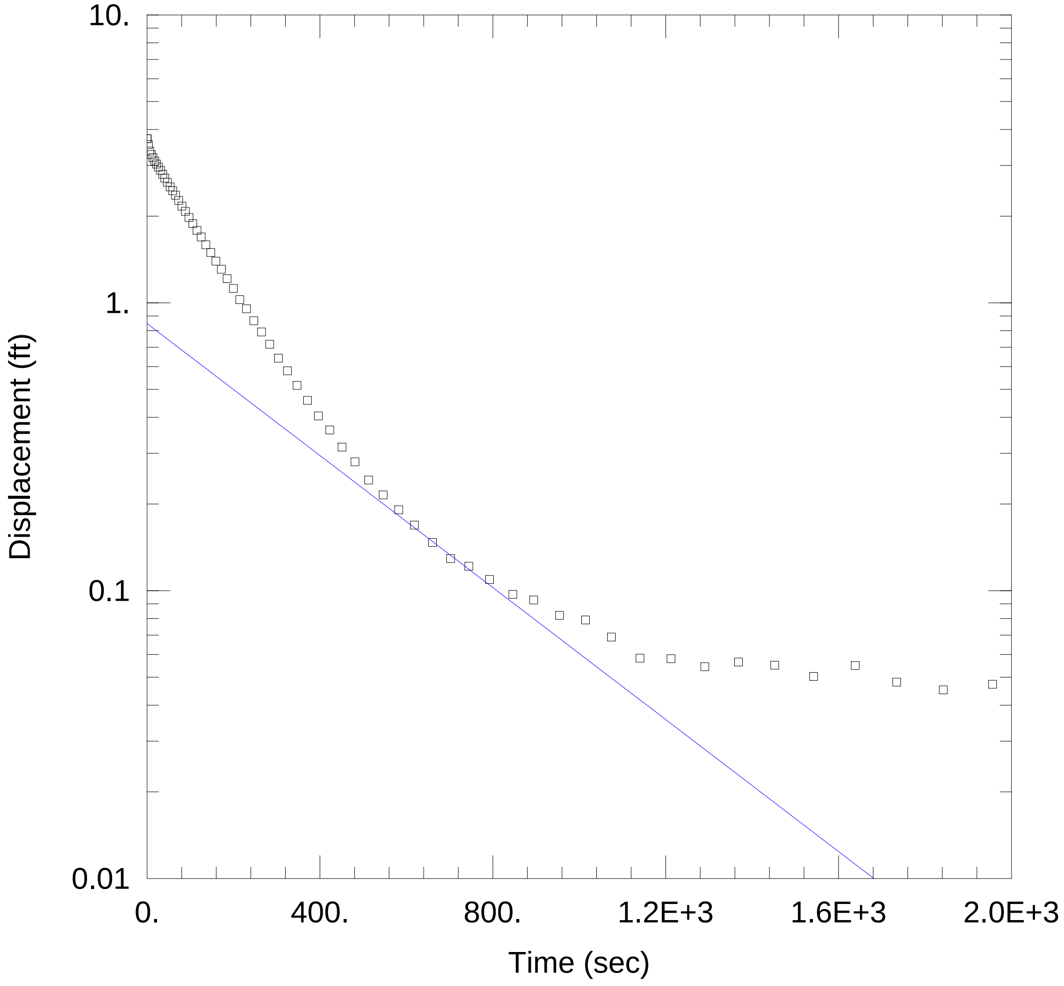
Parameter Correlations

	K	y0
K	1.00	0.66
y0	0.66	1.00

Residual Statistics

for weighted residuals

Sum of Squares	11.47 ft^2
Variance	0.1977 ft^2
Std. Deviation	0.4447 ft
Mean	0.000496 ft
No. of Residuals	60
No. of Estimates	2



WELL TEST ANALYSIS

Data Set: P:\...\GS7 SlugOut1.aqt

Date: 07/03/13 Time: 15:28:56

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS7
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 21.35 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS7 Slug Out 1)

Initial Displacement: 3.72 ft
Total Well Penetration Depth: 21.35 ft
Casing Radius: 0.0833 ft

Static Water Column Height: 21.35 ft
Screen Length: 10. ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.0001099 cm/sec y0 = 0.8468 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS7 SlugOut1.a
Date: 07/03/13
Time: 15:29:01

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS7

AQUIFER DATA

Saturated Thickness: 21.35 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS7 Slug Out 1

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 3.72 ft
Static Water Column Height: 21.35 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 10. ft
Total Well Penetration Depth: 21.35 ft

No. of Observations: 64

Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	3.713	283.7	0.7178
3.18	3.542	304.1	0.6421
6.54	3.366	325.1	0.5803
10.14	3.273	347.3	0.5164
13.74	3.194	371.3	0.4579
17.94	3.11	396.5	0.4045
22.14	3.032	422.9	0.3613
26.34	2.962	451.1	0.3151
31.14	2.881	481.1	0.2803
36.54	2.795	512.9	0.2422
41.34	2.71	546.5	0.215
47.34	2.622	582.5	0.1909
53.34	2.525	618.5	0.1688
59.34	2.45	660.5	0.1471
65.94	2.365	702.5	0.1293
73.14	2.266	744.5	0.1215
80.94	2.167	792.5	0.1093
88.74	2.078	846.5	0.097
97.14	1.978	894.5	0.09276
106.1	1.883	954.5	0.08209
115.7	1.784	1014.5	0.07906
125.3	1.692	1074.5	0.06899
136.1	1.591	1140.5	0.05823
147.5	1.495	1212.5	0.05799
159.5	1.395	1290.5	0.05446
172.1	1.307	1368.5	0.05648
185.3	1.213	1452.5	0.05506
199.7	1.121	1542.5	0.05033
214.7	1.026	1638.5	0.05492
230.3	0.9527	1734.5	0.04811

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
247.1	0.8656	1842.5	0.04521
265.1	0.7922	1956.5	0.04726

SOLUTION

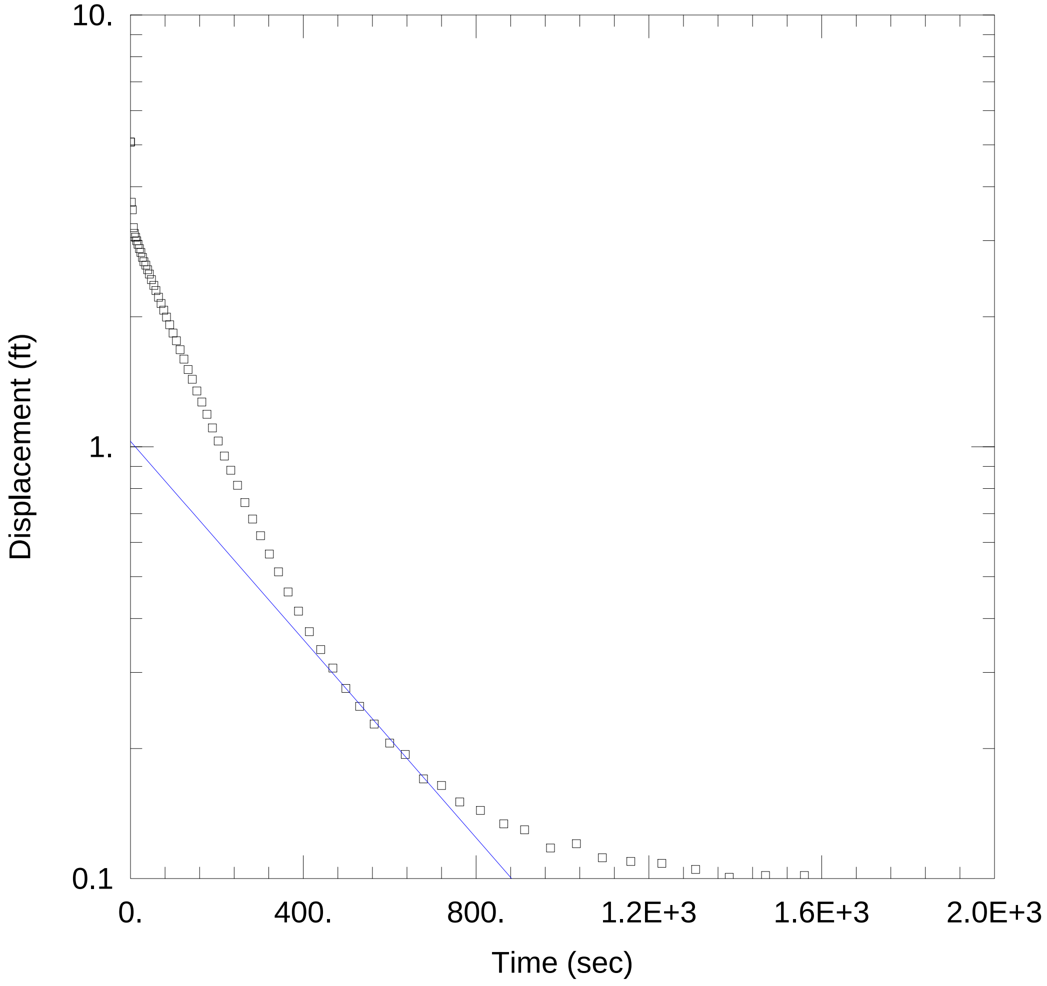
Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 4.176

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
K	0.0001099	cm/sec
y0	0.8468	ft

T = K*b = 0.07149 cm²/sec



WELL TEST ANALYSIS

Data Set: P:\...\GS7 SlugOut2.aqt
Date: 07/03/13 Time: 15:29:13

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS7
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 21.35 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS7 Slug Out 2)

Initial Displacement: 5.08 ft
Static Water Column Height: 21.35 ft
Total Well Penetration Depth: 21.35 ft
Screen Length: 10. ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.00011 cm/sec
y0 = 1.029 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS7 SlugOut2.a
Date: 07/03/13
Time: 15:29:17

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS7

AQUIFER DATA

Saturated Thickness: 21.35 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS7 Slug Out 2

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 5.08 ft
Static Water Column Height: 21.35 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 10. ft
Total Well Penetration Depth: 21.35 ft

No. of Observations: 67

Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	5.073	217.4	0.9515
2.1	3.682	232.4	0.882
4.32	3.537	248.	0.8137
6.72	3.215	264.8	0.742
9.24	3.118	282.8	0.6797
11.88	3.056	301.4	0.622
14.7	2.998	321.8	0.5638
17.7	2.941	342.8	0.5133
20.88	2.876	365.	0.4606
24.24	2.817	389.	0.4159
27.84	2.743	414.2	0.3729
31.44	2.682	440.6	0.3389
35.64	2.633	468.8	0.307
39.84	2.57	498.8	0.2756
44.04	2.512	530.6	0.2504
48.84	2.436	564.2	0.2279
54.24	2.363	600.2	0.2058
59.04	2.3	636.2	0.1937
65.04	2.219	678.2	0.1701
71.04	2.146	720.2	0.1642
77.04	2.071	762.2	0.1504
83.64	1.997	810.2	0.1437
90.84	1.916	864.2	0.1338
98.64	1.833	912.2	0.1297
106.4	1.76	972.2	0.1177
114.8	1.677	1032.2	0.1204
123.8	1.595	1092.2	0.1117
133.4	1.51	1158.2	0.1095
143.	1.433	1230.2	0.1084
153.8	1.346	1308.2	0.1049

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
165.2	1.27	1386.2	0.1006
177.2	1.188	1470.2	0.1016
189.8	1.106	1560.2	0.1016
203.	1.031		

SOLUTION

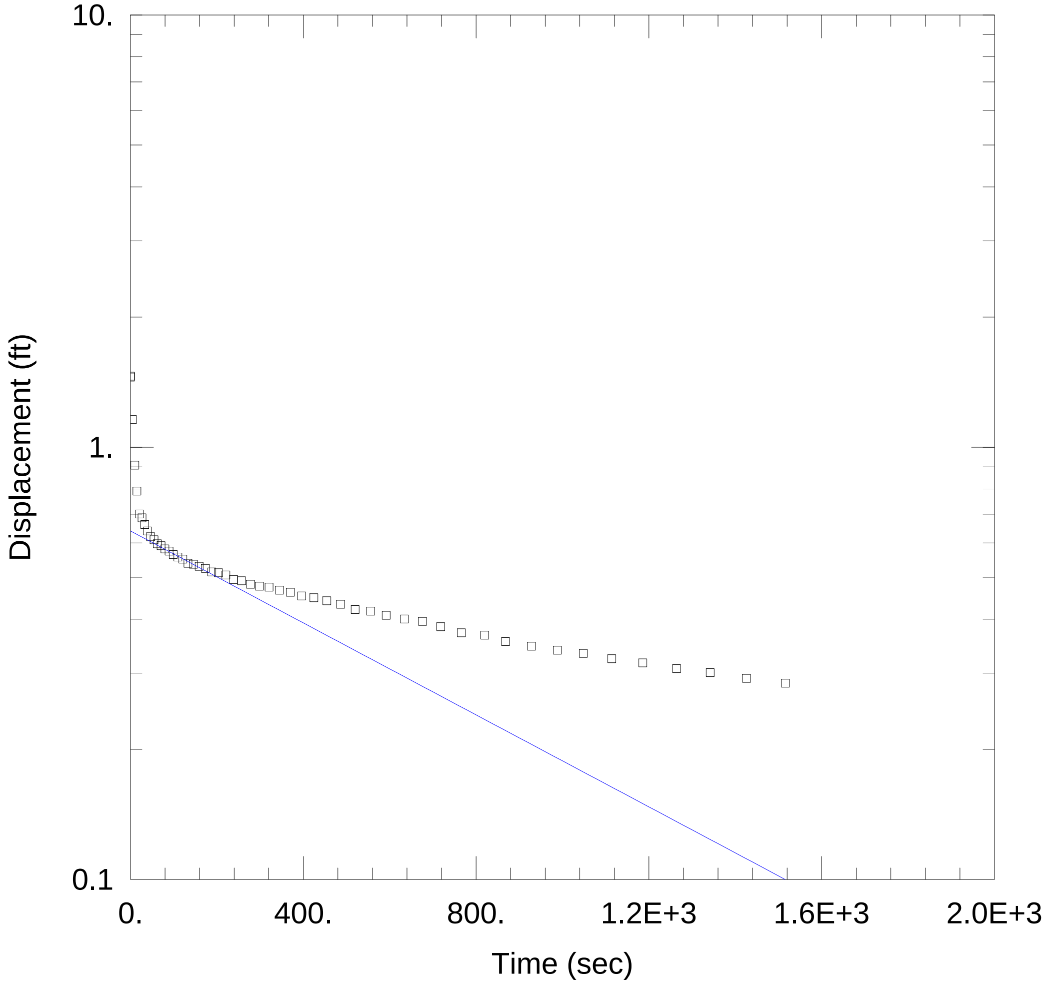
Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 4.176

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
K	0.00011	cm/sec
y0	1.029	ft

T = K*b = 0.07158 cm²/sec



WELL TEST ANALYSIS

Data Set: P:\...\GS8 SlugOut1.aqt
Date: 07/03/13
Time: 15:29:24

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Well: GS8
Test Date: May 1, 2013

AQUIFER DATA

Saturated Thickness: 6.46 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GS8 Slug Out 1)

Initial Displacement: 1.46 ft
Static Water Column Height: 6.46 ft
Total Well Penetration Depth: 6.46 ft
Screen Length: 6.46 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 6.316E-5 cm/sec
y0 = 0.64 ft

AQTESOLV for Windows

Data Set: P:\2000\2020\Task 1_Duck Creek Haul Road\Data\Slug Test Data\Files for AQTESOLV\GS8 SlugOut1.a
Date: 07/03/13
Time: 15:29:29

PROJECT INFORMATION

Company: NRT
Client: Ameren
Project: 2020
Location: Duck Creek
Test Date: May 1, 2013
Test Well: GS8

AQUIFER DATA

Saturated Thickness: 6.46 ft
Anisotropy Ratio (Kz/Kr): 1.

SLUG TEST WELL DATA

Test Well: GS8 Slug Out 1

X Location: 0. ft
Y Location: 0. ft

Initial Displacement: 1.46 ft
Static Water Column Height: 6.46 ft
Casing Radius: 0.0833 ft
Well Radius: 0.0833 ft
Well Skin Radius: 0.25 ft
Screen Length: 6.46 ft
Total Well Penetration Depth: 6.46 ft

No. of Observations: 53

Observation Data

Time (sec)	Displacement (ft)	Time (sec)	Displacement (ft)
0.01	1.452	298.8	0.477
4.8	1.159	321.	0.4742
10.2	0.9086	345.	0.4668
15.	0.7914	370.2	0.4617
21.	0.7005	396.6	0.4527
27.	0.686	424.8	0.4486
33.	0.6621	454.8	0.4411
39.6	0.6397	486.6	0.4331
46.8	0.6208	520.2	0.4211
54.6	0.6108	556.2	0.4176
62.4	0.5977	592.2	0.4081
70.8	0.5917	634.2	0.4002
79.8	0.5815	676.2	0.3952
89.4	0.5748	718.2	0.3843
99.	0.5647	766.2	0.3719
109.8	0.5569	820.2	0.3671
121.2	0.5507	868.2	0.3549
133.2	0.5386	928.2	0.3463
145.8	0.536	988.2	0.3391
159.	0.5302	1048.2	0.3331
173.4	0.524	1114.2	0.3241
188.4	0.5143	1186.2	0.3169
204.	0.5122	1264.2	0.3073
220.8	0.506	1342.2	0.3009
238.8	0.4941	1426.2	0.2918
257.4	0.4908	1516.2	0.2844
277.8	0.4819		

SOLUTION

Slug Test
Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
ln(Re/rw): 3.343

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
K	6.316E-5	cm/sec
y0	0.64	ft

T = K*b = 0.01244 cm²/sec

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	Std. Error	Approx. C.I.	t-Ratio	
K	4.694E-5	7.019E-6	+/- 1.409E-5	6.687	cm/sec
y0	0.7138	0.03317	+/- 0.06661	21.52	ft

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

T = K*b = 0.009242 cm²/sec

Parameter Correlations

	K	y0
K	1.00	0.64
y0	0.64	1.00

Residual Statistics

for weighted residuals

Sum of Squares	0.9977 ft^2
Variance	0.01956 ft^2
Std. Deviation	0.1399 ft
Mean	0.003605 ft
No. of Residuals	53
No. of Estimates	2

Attachment D

Laboratory Analytical Reports

Pace Analytical®
www.pacelabs.com

Pace Analytical Services, Inc.
1241 Bellevue Street - Suite 9
Green Bay, WI 54302
(920)469-2436

May 07, 2013

Bruce Hensel
Natural Resources Technologies
23713 W. Paul Rd
Ste D
Pewaukee, WI 53072

RE: Project: 2020 DUCK CREEK
Pace Project No.: 4077182

Dear Bruce Hensel:

Enclosed are the analytical results for sample(s) received by the laboratory on May 02, 2013. The results relate only to the samples included in this report. Results reported herein conform to the most current TNI 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,

Brian Basten

brian.basten@pacelabs.com
Project Manager

Enclosures

CERTIFICATIONS

Project:	2020 DUCK CREEK
Pace Project No.:	4077182

Green Bay Certification IDs

1241 Bellevue Street, Green Bay, WI 54302
Florida/NELAP Certification #: E87948
Illinois Certification #: 200050
Kentucky Certification #: 82
Louisiana Certification #: 04168
Minnesota Certification #: 055-999-334
New York Certification #: 11888
North Dakota Certification #: R-150
South Carolina Certification #: 83006001
US Dept of Agriculture #: S-76505
Wisconsin Certification #: 405132750

SAMPLE SUMMARY

Project: 2020 DUCK CREEK
Pace Project No.: 4077182

Lab ID	Sample ID	Matrix	Date Collected	Date Received
4077182001	**GS7/043013**	Water	04/30/13 16:04	05/02/13 09:55
4077182002	**GS1/043013**	Water	04/30/13 16:54	05/02/13 09:55
4077182003	**GS3/050113**	Water	05/01/13 06:55	05/02/13 09:55
4077182004	**GS4/050113**	Water	05/01/13 07:40	05/02/13 09:55
4077182005	**GS2/050113**	Water	05/01/13 08:35	05/02/13 09:55
4077182006	**GS5/050113**	Water	05/01/13 09:32	05/02/13 09:55
4077182007	**QC1/050113**	Water	05/01/13 09:35	05/02/13 09:55
4077182008	**GS6/050113**	Water	05/01/13 10:23	05/02/13 09:55
4077182009	**GS8/050113**	Water	05/01/13 10:52	05/02/13 09:55

SAMPLE ANALYTE COUNT

Project: 2020 DUCK CREEK
Pace Project No.: 4077182

Lab ID	Sample ID	Method	Analysts	Analytes Reported
4077182001	**GS7/043013**	EPA 6010	DLB	3
		EPA 300.0	JCJ	1
4077182002	**GS1/043013**	EPA 6010	DLB	3
		EPA 300.0	JCJ	1
4077182003	**GS3/050113**	EPA 6010	DLB	3
		EPA 300.0	JCJ	1
4077182004	**GS4/050113**	EPA 6010	DLB	3
		EPA 300.0	JCJ	1
4077182005	**GS2/050113**	EPA 6010	DLB	3
		EPA 300.0	JCJ	1
4077182006	**GS5/050113**	EPA 6010	DLB	3
		EPA 300.0	JCJ	1
4077182007	**QC1/050113**	EPA 6010	DLB	3
		EPA 300.0	JCJ	1
4077182008	**GS6/050113**	EPA 6010	DLB	3
		EPA 300.0	JCJ	1
4077182009	**GS8/050113**	EPA 6010	DLB	3
		EPA 300.0	JCJ	1

ANALYTICAL RESULTS

Project: 2020 DUCK CREEK
Pace Project No.: 4077182

Sample: GS7/043013 **Lab ID: 4077182001** Collected: 04/30/13 16:04 Received: 05/02/13 09:55 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Antimony	**<4.6**	ug/L	20.0	4.6	1	05/03/13 08:45	05/03/13 14:19	7440-36-0	
Boron	**11.1J**	ug/L	100	1.8	1	05/03/13 08:45	05/03/13 14:19	7440-42-8	
Chromium	**<1.4**	ug/L	5.0	1.4	1	05/03/13 08:45	05/03/13 14:19	7440-47-3	
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**83.2**	mg/L	20.0	10.0	5		05/06/13 23:18	14808-79-8	

Sample: GS1/043013 **Lab ID: 4077182002** Collected: 04/30/13 16:54 Received: 05/02/13 09:55 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Antimony	**<4.6**	ug/L	20.0	4.6	1	05/03/13 08:45	05/03/13 14:31	7440-36-0	
Boron	**804**	ug/L	100	1.8	1	05/03/13 08:45	05/03/13 14:31	7440-42-8	
Chromium	**<1.4**	ug/L	5.0	1.4	1	05/03/13 08:45	05/03/13 14:31	7440-47-3	
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**491**	mg/L	80.0	40.0	20		05/06/13 23:42	14808-79-8	

Sample: GS3/050113 **Lab ID: 4077182003** Collected: 05/01/13 06:55 Received: 05/02/13 09:55 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Antimony	**<4.6**	ug/L	20.0	4.6	1	05/03/13 08:45	05/03/13 14:34	7440-36-0	
Boron	**37.0J**	ug/L	100	1.8	1	05/03/13 08:45	05/03/13 14:34	7440-42-8	
Chromium	**2.8J**	ug/L	5.0	1.4	1	05/03/13 08:45	05/03/13 14:34	7440-47-3	
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**86.0**	mg/L	20.0	10.0	5		05/06/13 23:51	14808-79-8	

Sample: GS4/050113 **Lab ID: 4077182004** Collected: 05/01/13 07:40 Received: 05/02/13 09:55 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Antimony	**<4.6**	ug/L	20.0	4.6	1	05/03/13 08:45	05/03/13 14:36	7440-36-0	
Boron	**12.6J**	ug/L	100	1.8	1	05/03/13 08:45	05/03/13 14:36	7440-42-8	
Chromium	**1.6J**	ug/L	5.0	1.4	1	05/03/13 08:45	05/03/13 14:36	7440-47-3	

ANALYTICAL RESULTS

Project: 2020 DUCK CREEK
Pace Project No.: 4077182

Sample: GS4/050113 **Lab ID: 4077182004** Collected: 05/01/13 07:40 Received: 05/02/13 09:55 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**225**	mg/L	40.0	20.0	10		05/07/13 00:15	14808-79-8	

Sample: GS2/050113 **Lab ID: 4077182005** Collected: 05/01/13 08:35 Received: 05/02/13 09:55 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Antimony	**<4.6**	ug/L	20.0	4.6	1	05/03/13 08:45	05/03/13 14:38	7440-36-0	
Boron	**58.2J**	ug/L	100	1.8	1	05/03/13 08:45	05/03/13 14:38	7440-42-8	
Chromium	**<1.4**	ug/L	5.0	1.4	1	05/03/13 08:45	05/03/13 14:38	7440-47-3	
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**667**	mg/L	80.0	40.0	20		05/07/13 00:23	14808-79-8	

Sample: GS5/050113 **Lab ID: 4077182006** Collected: 05/01/13 09:32 Received: 05/02/13 09:55 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Antimony	**<4.6**	ug/L	20.0	4.6	1	05/03/13 08:45	05/03/13 14:40	7440-36-0	
Boron	**7970**	ug/L	100	1.8	1	05/03/13 08:45	05/03/13 14:40	7440-42-8	
Chromium	**<1.4**	ug/L	5.0	1.4	1	05/03/13 08:45	05/03/13 14:40	7440-47-3	
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**1820**	mg/L	400	200	100		05/07/13 00:31	14808-79-8	

Sample: QC1/050113 **Lab ID: 4077182007** Collected: 05/01/13 09:35 Received: 05/02/13 09:55 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Antimony	**<4.6**	ug/L	20.0	4.6	1	05/03/13 08:45	05/03/13 14:43	7440-36-0	
Boron	**8140**	ug/L	100	1.8	1	05/03/13 08:45	05/03/13 14:43	7440-42-8	
Chromium	**<1.4**	ug/L	5.0	1.4	1	05/03/13 08:45	05/03/13 14:43	7440-47-3	
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**1800**	mg/L	400	200	100		05/07/13 00:40	14808-79-8	

ANALYTICAL RESULTS

Project: 2020 DUCK CREEK
Pace Project No.: 4077182

Sample: GS6/050113 **Lab ID: 4077182008** Collected: 05/01/13 10:23 Received: 05/02/13 09:55 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Antimony	**<4.6**	ug/L	20.0	4.6	1	05/03/13 08:45	05/03/13 14:45	7440-36-0	
Boron	**104**	ug/L	100	1.8	1	05/03/13 08:45	05/03/13 14:45	7440-42-8	
Chromium	**<1.4**	ug/L	5.0	1.4	1	05/03/13 08:45	05/03/13 14:45	7440-47-3	
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**699**	mg/L	200	100	50		05/07/13 00:48	14808-79-8	

Sample: GS8/050113 **Lab ID: 4077182009** Collected: 05/01/13 10:52 Received: 05/02/13 09:55 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Antimony	**<4.6**	ug/L	20.0	4.6	1	05/03/13 08:45	05/03/13 14:48	7440-36-0	
Boron	**95.1J**	ug/L	100	1.8	1	05/03/13 08:45	05/03/13 14:48	7440-42-8	
Chromium	**1.5J**	ug/L	5.0	1.4	1	05/03/13 08:45	05/03/13 14:48	7440-47-3	
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Sulfate	**1530**	mg/L	400	200	100		05/07/13 00:56	14808-79-8	

QUALITY CONTROL DATA

Project: 2020 DUCK CREEK
Pace Project No.: 4077182

QC Batch: MPRP/8423
Analysis Method: EPA 6010
QC Batch Method: EPA 3010
Analysis Description: 6010 MET
Associated Lab Samples: 4077182001, 4077182002, 4077182003, 4077182004, 4077182005, 4077182006, 4077182007, 4077182008, 4077182009

METHOD BLANK: 783702
Matrix: Water
Associated Lab Samples: 4077182001, 4077182002, 4077182003, 4077182004, 4077182005, 4077182006, 4077182007, 4077182008, 4077182009

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Antimony	ug/L	<4.6	20.0	05/03/13 14:13	
Boron	ug/L	<1.8	100	05/03/13 14:13	
Chromium	ug/L	<1.4	5.0	05/03/13 14:13	

LABORATORY CONTROL SAMPLE: 783703

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Antimony	ug/L	500	496	99	80-120	
Boron	ug/L	500	476	95	80-120	
Chromium	ug/L	500	487	97	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 783704 783705

Parameter	Units	4077182001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Antimony	ug/L	<4.6	500	500	502	501	100	100	75-125	0	20	
Boron	ug/L	11.1J	500	500	490	485	96	95	75-125	1	20	
Chromium	ug/L	<1.4	500	500	486	480	97	96	75-125	1	20	

QUALITY CONTROL DATA

Project: 2020 DUCK CREEK
Pace Project No.: 4077182

QC Batch: WETA/17439 Analysis Method: EPA 300.0
QC Batch Method: EPA 300.0 Analysis Description: 300.0 IC Anions
Associated Lab Samples: 4077182001, 4077182002, 4077182003, 4077182004, 4077182005, 4077182006, 4077182007, 4077182008, 4077182009

METHOD BLANK: 785132 Matrix: Water
Associated Lab Samples: 4077182001, 4077182002, 4077182003, 4077182004, 4077182005, 4077182006, 4077182007, 4077182008, 4077182009

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Sulfate	mg/L	<2.0	4.0	05/06/13 09:27	

LABORATORY CONTROL SAMPLE: 785133

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Sulfate	mg/L	20	19.5	98	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 785134 785135

Parameter	Units	4077182001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Sulfate	mg/L	83.2	100	100	182	183	99	100	90-110	0	20	

QUALIFIERS

Project:	2020 DUCK CREEK
Pace Project No.:	4077182

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to changes in sample preparation, dilution of the sample aliquot, or moisture content.

ND - Not Detected at or above adjusted reporting limit.

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

MDL - Adjusted Method Detection Limit.

PRL - Pace Reporting Limit.

RL - Reporting Limit.

S - Surrogate

1,2-Diphenylhydrazine (8270 listed analyte) decomposes to Azobenzene.

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.

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: 2020 DUCK CREEK
Pace Project No.: 4077182

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
4077182001	**GS7/043013**	EPA 3010	MPRP/8423	EPA 6010	ICP/7471
4077182002	**GS1/043013**	EPA 3010	MPRP/8423	EPA 6010	ICP/7471
4077182003	**GS3/050113**	EPA 3010	MPRP/8423	EPA 6010	ICP/7471
4077182004	**GS4/050113**	EPA 3010	MPRP/8423	EPA 6010	ICP/7471
4077182005	**GS2/050113**	EPA 3010	MPRP/8423	EPA 6010	ICP/7471
4077182006	**GS5/050113**	EPA 3010	MPRP/8423	EPA 6010	ICP/7471
4077182007	**QC1/050113**	EPA 3010	MPRP/8423	EPA 6010	ICP/7471
4077182008	**GS6/050113**	EPA 3010	MPRP/8423	EPA 6010	ICP/7471
4077182009	**GS8/050113**	EPA 3010	MPRP/8423	EPA 6010	ICP/7471
4077182001	**GS7/043013**	EPA 300.0	WETA/17439		
4077182002	**GS1/043013**	EPA 300.0	WETA/17439		
4077182003	**GS3/050113**	EPA 300.0	WETA/17439		
4077182004	**GS4/050113**	EPA 300.0	WETA/17439		
4077182005	**GS2/050113**	EPA 300.0	WETA/17439		
4077182006	**GS5/050113**	EPA 300.0	WETA/17439		
4077182007	**QC1/050113**	EPA 300.0	WETA/17439		
4077182008	**GS6/050113**	EPA 300.0	WETA/17439		
4077182009	**GS8/050113**	EPA 300.0	WETA/17439		

(Please Print Clearly)

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UPPER MIDWEST REGION
MN: 612-607-1700 WI: 920-469-2436

Page 1 of 1

4077182
COC# 2020 001

CHAIN OF CUSTODY

Company Name: Natural Resource Technology
Branch/Location: Pewaukee, WI
Project Contact: ~~Bruce Hensel~~ Eric Kovatch
Phone: 262-523-9000
Project Number: 2020
Project Name: Duck Creek
Project State: IL
Sampled By (Print): Jacob Walczak
Sampled By (Sign):
PO #:
Regulatory Program:

*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

JOM

Quote #:
EMail To Contact: Jody Barbeau jbarbeau@naturalrt.com
EMail To Company: Natural Resource Tech.
Mail To Address: 23713 W. Paul Rd. Ste. D
Pewaukee, WI 53072
Invoice To Contact: Tracy
Invoice To Company: Natural Resource Tech
Invoice To Address: 23713 W. Paul Rd Ste D
Pewaukee WI 53072
Invoice To Phone: 262-523-9000

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	W = Water
B = Biota	DW = Drinking Water
C = Charcoal	GW = Ground Water
O = Oil	SW = Surface Water
S = Soil	WW = Waste Water
SI = Sludge	WP = Wipe

FILTERED? (YES/NO) — Y / N: N, N
PRESERVATION (CODE)* — Pick Letter: D, A

Analyses Requested: Boron, Antimony, Chromium by 6010; Sulfate

PACE LAB #	CLIENT FIELD ID	COLLECTION DATE	COLLECTION TIME	MATRIX	Boron, Antimony, Chromium by 6010	Sulfate	CLIENT COMMENTS	LAB COMMENTS (Lab Use Only)	Profile #
001	GS7/043013	4-30-13	1604	GW	X	X	Rush TAT	2-250mlp AD	
002	GS1/043013	4-30-13	1654		X	X			
003	GS3/050113	5-1-13	6:55		X	X			
004	GS4/050113		7:40		X	X			
005	GS2/050113		8:35		X	X			
006	GS5/050113		9:32		X	X			
007	QC1/050113		9:35		X	X			
008	GS6/050113		10:23		X	X			
009	GS8/050113		10:52		X	X			

Rush Turnaround Time Requested - Prelims
(Rush TAT subject to approval/surcharge)
Date Needed:

Transmit Prelim Rush Results by (complete what you want):
Email #1: Bruce Hensel bhensel@naturalrt.com
Email #2: Eric Kovatch ekovatch@naturalrt.com
Telephone:
Fax:

Samples on HOLD are subject to special pricing and release of liability

Relinquished By:	Date/Time:	Received By:	Date/Time:
	5-1-13 12:30		
Fedex	5/2/13 0955		5/2/13 0955

PACE Project No. 4077182
Receipt Temp = 2 °C
Sample Receipt pH [✓ OK] / Adjusted
Cooler Custody Seal [✓ Present] / Not Present
[✓ Intact] / Not Intact

Version 6.0 06/14/06

C019a(27Jun2006)

Custody Seal # 2020050113

Pace Analytical™

Pace Analytical Services, Inc.
1241 Bellevue Street, Suite
Green Bay, WI 54302

Sample Condition Upon Receipt

Client Name: NRT **Project #** 4077182

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

Tracking #: 799657783500

Custody Seal on Cooler/Box Present: ☑ yes ☐ no Seals intact: ☑ yes ☐ no

Custody Seal on Samples Present: ☐ yes ☑ no Seals intact: ☐ yes ☐ no

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

Thermometer Used SR-13 **Type of Ice:** [✓ Wet] Blue Dry None ☑ Samples on ice, cooling process has begun

Cooler Temperature Uncorr: 2 /Corr: 2 **Biological Tissue is Frozen:** ☐ yes ☐ no

Temp Blank Present: ☐ yes ☑ no

Temp should be above freezing to 6°C for all sample except Biota.
Frozen Biota Samples should be received ≤ 0°C.

Person examining contents:
Date: 5/2/13
Initials: [illegible]

Comments:

Chain of Custody Present:	☑Yes	☐No	☐N/A	1.
Chain of Custody Filled Out:	☑Yes	☐No	☐N/A	2.
Chain of Custody Relinquished:	☑Yes	☐No	☐N/A	3.
Sampler Name & Signature on COC:	☑Yes	☐No	☐N/A	4.
Samples Arrived within Hold Time:	☑Yes	☐No	☐N/A	5.
- VOA Samples frozen upon receipt	☐Yes	☐No		Date/Time:
Short Hold Time Analysis (<72hr):	☐Yes	☑No	☐N/A	6.
Rush Turn Around Time Requested:	☑Yes	☐No	☐N/A	7. Rush [illegible] 5/2/13
Sufficient Volume:	☑Yes	☐No	☐N/A	8.
Correct Containers Used:	☑Yes	☐No	☐N/A	9.
-Pace Containers Used:	☑Yes	☐No	☐N/A	
-Pace IR Containers Used:	☐Yes	☐No	☑N/A	
Containers Intact:	☑Yes	☐No	☐N/A	10.
Filtered volume received for Dissolved tests	☐Yes	☐No	☑N/A	11.
Sample Labels match COC:	☑Yes	☐No	☐N/A	12.
-Includes date/time/ID/Analysis Matrix: W				
All containers needing preservation have been checked. (Non-Compliance noted in 13.)	☑Yes	☐No	☐N/A	13. ☑ HNO3 ☐ H2SO4 ☐ NaOH ☐ NaOH +ZnAct
All containers needing preservation are found to be in compliance with EPA recommendation. (HNO3, H2SO4 ≤2; NaOH+ZnAct ≥9, NaOH ≥12)	☑Yes	☐No	☐N/A	
exceptions: VOA, coliform, TOC, TOX, TOH, O&G, WIDROW, Phenolics, OTHER: ____	☐Yes	☑No		Initial when completed [illegible] Lab Std #ID of preservative ____ Date/ Time: ____
Headspace in VOA Vials (>6mm):	☐Yes	☐No	☑N/A	14.
Trip Blank Present:	☐Yes	☐No	☑N/A	15.
Trip Blank Custody Seals Present	☐Yes	☐No	☑N/A	
Pace Trip Blank Lot # (if purchased): ____				

Client Notification/ Resolution: If checked, see attached form for additional comments ☐

Person Contacted: ____ Date/Time: ____

Comments/ Resolution: ____

Project Manager Review: ____ **Date:** 5-2-13

Pace Analytical®
www.pacelabs.com

Pace Analytical Services, Inc.
1241 Bellevue Street - Suite 9
Green Bay, WI 54302
(920)469-2436

July 17, 2013

Bruce Hensel
Natural Resources Technologies
234 W. Florida St, 5th Floor
Milwaukee, WI 53204

RE: Project: 2020/1.0 DUCK CREEK
Pace Project No.: 4079153

Dear Bruce Hensel:

Enclosed are the analytical results for sample(s) received by the laboratory on June 06, 2013. The results relate only to the samples included in this report. Results reported herein conform to the most current TNI 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,

Brian Basten

brian.basten@pacelabs.com
Project Manager

Enclosures

CERTIFICATIONS

Project: 2020/1.0 DUCK CREEK
Pace Project No.: 4079153

Minnesota Certification IDs

1700 Elm Street SE Suite 200, Minneapolis, MN 55414
A2LA Certification #: 2926.01
Alaska Certification #: UST-078
Alaska Certification #MN00064
Arizona Certification #: AZ-0014
Arkansas Certification #: 88-0680
California Certification #: 01155CA
Colorado Certification #Pace
Connecticut Certification #: PH-0256
EPA Region 8 Certification #: Pace
Florida/NELAP Certification #: E87605
Georgia Certification #: 959
Hawaii Certification #Pace
Idaho Certification #: MN00064
Illinois Certification #: 200011
Kansas Certification #: E-10167
Louisiana Certification #: 03086
Louisiana Certification #: LA080009
Maine Certification #: 2007029
Maryland Certification #: 322
Michigan DEQ Certification #: 9909
Minnesota Certification #: 027-053-137
Mississippi Certification #: Pace
Montana Certification #: MT CERT0092
Nebraska Certification #: Pace
Nevada Certification #: MN_00064
New Jersey Certification #: MN-002
New York Certification #: 11647
North Carolina Certification #: 530
North Dakota Certification #: R-036
Ohio VAP Certification #: CL101
Oklahoma Certification #: 9507
Oregon Certification #: MN200001
Oregon Certification #: MN300001
Pennsylvania Certification #: 68-00563
Puerto Rico Certification
Tennessee Certification #: 02818
Texas Certification #: T104704192
Utah Certification #: MN00064
Virginia/DCLS Certification #: 002521
Virginia/VELAP Certification #: 460163
Washington Certification #: C754
West Virginia Certification #: 382
Wisconsin Certification #: 999407970

Green Bay Certification IDs

1241 Bellevue Street, Green Bay, WI 54302
Florida/NELAP Certification #: E87948
Illinois Certification #: 200050
Kentucky Certification #: 82
Louisiana Certification #: 04168
Minnesota Certification #: 055-999-334
New York Certification #: 11888
North Dakota Certification #: R-150
South Carolina Certification #: 83006001
US Dept of Agriculture #: S-76505
Wisconsin Certification #: 405132750

SAMPLE SUMMARY

Project:	2020/1.0 DUCK CREEK
Pace Project No.:	4079153

Lab ID	Sample ID	Matrix	Date Collected	Date Received
4079153001	**GS5**	Water	06/05/13 09:50	06/06/13 09:30

SAMPLE ANALYTE COUNT

Project: 2020/1.0 DUCK CREEK
Pace Project No.: 4079153

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
4079153001	**GS5**	EPA 6020	TT3	1	PASI-M
		EPA 6020	MMZ	11	PASI-G
		EPA 300.0	JCJ	4	PASI-G

ANALYTICAL RESULTS

Project: 2020/1.0 DUCK CREEK
Pace Project No.: 4079153

Sample: GS5 **Lab ID: 4079153001** Collected: 06/05/13 09:50 Received: 06/06/13 09:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6020 MET ICPMS	Analytical Method: EPA 6020 Preparation Method: EPA 3020								
Silicon	**4540**	ug/L	125	43.8	5	06/20/13 07:18	06/27/13 10:46	7440-21-3	
6020 MET ICPMS	Analytical Method: EPA 6020 Preparation Method: EPA 3010								
Antimony	**<0.054**	ug/L	1.0	0.054	1	06/10/13 08:45	06/11/13 17:42	7440-36-0	
Barium	**8.4**	ug/L	1.0	0.062	1	06/10/13 08:45	06/11/13 17:42	7440-39-3	
Boron	**7630**	ug/L	20.0	2.7	2	06/10/13 08:45	06/13/13 12:39	7440-42-8	
Calcium	**549000**	ug/L	500	218	2	06/10/13 08:45	06/13/13 12:39	7440-70-2	
Lithium	**49.9**	ug/L	1.0	0.21	1	06/10/13 08:45	06/11/13 17:42	7439-93-2	
Magnesium	**211000**	ug/L	250	13.1	1	06/10/13 08:45	06/11/13 17:42	7439-95-4	
Molybdenum	**<0.13**	ug/L	1.0	0.13	1	06/10/13 08:45	06/11/13 17:42	7439-98-7	
Potassium	**3830**	ug/L	250	46.3	1	06/10/13 08:45	06/11/13 17:42	7440-09-7	
Sodium	**25300**	ug/L	250	8.1	1	06/10/13 08:45	06/11/13 17:42	7440-23-5	
Strontium	**863**	ug/L	1.0	0.030	1	06/10/13 08:45	06/11/13 17:42	7440-24-6	
Vanadium	**<0.37**	ug/L	1.0	0.37	1	06/10/13 08:45	06/11/13 17:42	7440-62-2	
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Bromide	**<0.20**	mg/L	0.40	0.20	1		06/11/13 10:18	24959-67-9	
Chloride	**5.4**	mg/L	4.0	2.0	1		06/11/13 10:18	16887-00-6	M0
Fluoride	**0.41**	mg/L	0.40	0.20	1		06/11/13 10:18	16984-48-8	M0
Sulfate	**1800**	mg/L	400	200	100		06/11/13 20:01	14808-79-8	

QUALITY CONTROL DATA

Project: 2020/1.0 DUCK CREEK
Pace Project No.: 4079153

QC Batch: MPRP/40045
Analysis Method: EPA 6020
QC Batch Method: EPA 3020
Analysis Description: 6020 MET
Associated Lab Samples: 4079153001

METHOD BLANK: 1461150
Matrix: Water
Associated Lab Samples: 4079153001

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Silicon	ug/L	25.1	25.0	06/27/13 10:41	P8

LABORATORY CONTROL SAMPLE: 1461151

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Silicon	ug/L	1000	1010	101	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1461183 1461184

Parameter	Units	4079153003 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Silicon	ug/L	586	1000	1000	1600	1570	102	99	75-125	2	20	

QUALITY CONTROL DATA

Project: 2020/1.0 DUCK CREEK
Pace Project No.: 4079153

QC Batch: MPRP/8598
Analysis Method: EPA 6020
QC Batch Method: EPA 3010
Analysis Description: 6020 MET
Associated Lab Samples: 4079153001

METHOD BLANK: 805291
Matrix: Water
Associated Lab Samples: 4079153001

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Antimony	ug/L	<0.054	1.0	06/11/13 16:05	
Barium	ug/L	<0.062	1.0	06/11/13 16:05	
Boron	ug/L	<1.4	10.0	06/11/13 16:05	
Calcium	ug/L	<109	250	06/11/13 16:05	
Lithium	ug/L	<0.21	1.0	06/11/13 16:05	
Magnesium	ug/L	<13.1	250	06/11/13 16:05	
Molybdenum	ug/L	<0.13	1.0	06/11/13 16:05	
Potassium	ug/L	<46.3	250	06/11/13 16:05	
Sodium	ug/L	31.1J	250	06/11/13 16:05	
Strontium	ug/L	<0.030	1.0	06/11/13 16:05	
Vanadium	ug/L	<0.37	1.0	06/11/13 16:05	

LABORATORY CONTROL SAMPLE: 805292

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Antimony	ug/L	500	527	105	80-120	
Barium	ug/L	500	494	99	80-120	
Boron	ug/L	500	431	86	80-120	
Calcium	ug/L	5000	4960	99	80-120	
Lithium	ug/L	500	453	91	80-120	
Magnesium	ug/L	5000	4850	97	80-120	
Molybdenum	ug/L	500	488	98	80-120	
Potassium	ug/L	5000	4500	90	80-120	
Sodium	ug/L	5000	4820	96	80-120	
Strontium	ug/L	500	499	100	80-120	
Vanadium	ug/L	500	484	97	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 805293 805294

Parameter	Units	4078981001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Antimony	ug/L	<0.054	500	500	528	522	106	104	75-125	1	20	
Barium	ug/L	61.2	500	500	560	545	100	97	75-125	3	20	
Boron	ug/L	359	500	500	798	782	88	85	75-125	2	20	
Calcium	ug/L	106000	5000	5000	112000	122000	124	320	75-125	8	20	P6
Lithium	ug/L	12.8	500	500	462	452	90	88	75-125	2	20	
Magnesium	ug/L	44000	5000	5000	49200	50100	103	121	75-125	2	20	
Molybdenum	ug/L	3.0	500	500	497	490	99	97	75-125	1	20	
Potassium	ug/L	4670	5000	5000	9680	9660	100	100	75-125	0	20	
Sodium	ug/L	49000	5000	5000	54300	55300	106	125	75-125	2	20	

QUALITY CONTROL DATA

Project: 2020/1.0 DUCK CREEK
Pace Project No.: 4079153

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 805293 805294

Parameter	Units	4078981001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Strontium	ug/L	21600	500	500	22200	22300	124	140	75-125	0	20	P6
Vanadium	ug/L	<0.37	500	500	486	484	97	97	75-125	0	20	

QUALITY CONTROL DATA

Project: 2020/1.0 DUCK CREEK
Pace Project No.: 4079153

QC Batch: WETA/18030
Analysis Method: EPA 300.0
QC Batch Method: EPA 300.0
Analysis Description: 300.0 IC Anions
Associated Lab Samples: 4079153001

METHOD BLANK: 805632
Matrix: Water
Associated Lab Samples: 4079153001

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Bromide	mg/L	<0.20	0.40	06/11/13 09:56	
Chloride	mg/L	<2.0	4.0	06/11/13 09:56	
Fluoride	mg/L	<0.20	0.40	06/11/13 09:56	
Sulfate	mg/L	<2.0	4.0	06/11/13 19:39	

LABORATORY CONTROL SAMPLE: 805633

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Bromide	mg/L	2	2.0	100	90-110	
Chloride	mg/L	20	18.8	94	90-110	
Fluoride	mg/L	2	1.9	96	90-110	
Sulfate	mg/L	20	19.4	97	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 805634 805635

Parameter	Units	4079153001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Bromide	mg/L	<0.20	2	2	2.0	2.1	101	103	90-110	2	20	
Chloride	mg/L	5.4	20	20	23.1	23.3	88	89	90-110	1	20	M0
Fluoride	mg/L	0.41	2	2	2.4	2.6	102	111	90-110	7	20	M0
Sulfate	mg/L	1800	2000	2000	3800	3800	100	100	90-110	0	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 805636 805637

Parameter	Units	4079287001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Bromide	mg/L	<1.0	10	10	10.1	10.1	101	101	90-110	0	20	
Chloride	mg/L	37.0	100	100	130	130	93	93	90-110	0	20	
Fluoride	mg/L	1.5J	10	10	10.4	10.4	90	90	90-110	0	20	
Sulfate	mg/L	276	200	200	492	495	108	109	90-110	1	20	

QUALIFIERS

Project:	2020/1.0 DUCK CREEK
Pace Project No.:	4079153

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to changes in sample preparation, dilution of the sample aliquot, or moisture content.

ND - Not Detected at or above adjusted reporting limit.

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

MDL - Adjusted Method Detection Limit.

PRL - Pace Reporting Limit.

RL - Reporting Limit.

S - Surrogate

1,2-Diphenylhydrazine (8270 listed analyte) decomposes to Azobenzene.

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-G	Pace Analytical Services - Green Bay
PASI-M	Pace Analytical Services - Minneapolis

ANALYTE QUALIFIERS

M0	Matrix spike recovery and/or matrix spike duplicate recovery was outside laboratory control limits.
P6	Matrix spike recovery was outside laboratory control limits due to a parent sample concentration notably higher than the spike level.
P8	Analyte was detected in the method blank. All associated samples had concentrations of at least ten times greater than the blank or were below the reporting limit.

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: 2020/1.0 DUCK CREEK
Pace Project No.: 4079153

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
4079153001	**GS5**	EPA 3020	MPRP/40045	EPA 6020	ICPM/16599
4079153001	**GS5**	EPA 3010	MPRP/8598	EPA 6020	ICPM/3820
4079153001	**GS5**	EPA 300.0	WETA/18030		

Pace Analytical®
www.pacelabs.com

CHAIN OF CUSTODY

UPPER MIDWEST REGION
MN: 612-607-1700 **WI:** 920-469-2436

Page 1 of 1

4079153

(Please Print Clearly)

Company Name:	NRT
Branch/Location:	Milwaukee
Project Contact:	Eric Kovatch
Phone:	262.719.4506
Project Number:	2020/1.0
Project Name:	Duck Creek
Project State:	IL
Sampled By (Print):	Eric P. Kovatch
Sampled By (Sign):	Eric P. Kovatch
PO #:	
Regulatory Program:	

Quote #:	Duck Creek
Mail To Contact:	Eric Kovatch
Mail To Company:	NRT
Mail To Address:	234 W. Florida St 5th Floor Milwaukee 53204
Invoice To Contact:	Tracy Summit
Invoice To Company:	Same
Invoice To Address:	Same
Invoice To Phone:	

*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

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	W = Water
B = Biota	DW = Drinking Water
C = Charcoal	GW = Ground Water
O = Oil	SW = Surface Water
S = Soil	WW = Waste Water
Sl = Sludge	WP = Wipe

				FILTERED? (YES/NO)	Y/N	X	Y	N		
				PRESERVATION (CODE)*	Pick Letter	X	D	A		
					Analyses Requested	ASTM Leach	Metals	Inorganic Cl, SO_4, Fl, Br		
PACE LAB #	**CLIENT FIELD ID**	**COLLECTION DATE**	**COLLECTION TIME**	**MATRIX**					**CLIENT COMMENTS**	**LAB COMMENTS (Lab Use Only)**
001	GS5	6/5/13	0950	Water			1	1	Refer to	2-250mlp AD
002	GS5A 13-15	↓	1030	Soil		3			Bottle order	3-4oz ag A
003	GS5A 17-19	↓	1045	↓		3			Sheet for	↓
004	GS5A 23-25	↓	1100	↓		3			Analyses	↓
005	GS5B 8-10	↓	1140	↓		3				↓
006	GS5B 12-14	↓	1200	↓		3			* Call EPK	↓
007	GS5B 16-18	↓	1215	↓		3			w/ questions	↓

Profile #

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:
E. P. Kovatch	6/5/13 1445	Fed Ex	
FedEx	6/6/13 0930	E Helwig Pace GB	6/6/13 0930

PACE Project No. 4079153

Receipt Temp = 2 °C

Sample Receipt pH
OK / Adjusted

Cooler Custody Seal
Present / [✓ Not Present]
Intact / Not Intact

Version 6.0 06/14/06

C019a(27Jun2006)

Pace Analytical™

Pace Analytical Services, Inc.
1241 Bellevue Street, Suite 9
Green Bay, WI 54302

Sample Condition Upon Receipt

Client Name: NRT   Project # 4079153

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

Tracking #: 8022 3015 4348

Custody Seal on Cooler/Box Present: ☐ yes ☑ no   Seals intact: ☐ yes ☐ no

Custody Seal on Samples Present: ☐ yes ☑ no   Seals intact: ☐ yes ☐ no

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

Thermometer Used SR45   **Type of Ice:** [✓ Wet] Blue Dry None   ☑ Samples on ice, cooling process has begun

Cooler Temperature Uncorr: 2 /Corr: 2   **Biological Tissue is Frozen:** ☐ yes ☐ no

Temp Blank Present: ☑ yes ☐ no

Temp should be above freezing to 6°C for all sample except Biota.
Frozen Biota Samples should be received ≤ 0°C.

Person examining contents:
Date: 6/6/13
Initials: EMH

		Comments:
Chain of Custody Present:	☑Yes ☐No ☐N/A	1.
Chain of Custody Filled Out:	☑Yes ☐No ☐N/A	2.
Chain of Custody Relinquished:	☑Yes ☐No ☐N/A	3.
Sampler Name & Signature on COC:	☑Yes ☐No ☐N/A	4.
Samples Arrived within Hold Time:	☑Yes ☐No ☐N/A	5.
- VOA Samples frozen upon receipt	☐Yes ☐No	Date/Time:
Short Hold Time Analysis (<72hr):	☐Yes ☑No ☐N/A	6.
Rush Turn Around Time Requested:	☐Yes ☑No ☐N/A	7.
Sufficient Volume:	☑Yes ☐No ☐N/A	8.
Correct Containers Used:	☑Yes ☐No ☐N/A	9.
-Pace Containers Used:	☑Yes ☐No ☐N/A	
-Pace IR Containers Used:	☐Yes ☐No ☑N/A	
Containers Intact:	☑Yes ☐No ☐N/A	10.
Filtered volume received for Dissolved tests	☑Yes ☐No ☐N/A	11.
Sample Labels match COC:	☑Yes ☐No ☐N/A	12.
-Includes date/time/ID/Analysis Matrix: W/S		
All containers needing preservation have been checked. (Non-Compliance noted in 13.)	☑Yes ☐No ☐N/A	13. ☑ HNO3 ☐ H2SO4 ☐ NaOH ☐ NaOH +ZnAct
All containers needing preservation are found to be in compliance with EPA recommendation. (HNO3, H2SO4 ≤2; NaOH+ZnAct ≥9, NaOH ≥12)	☑Yes ☐No ☐N/A	
exceptions: VOA, coliform, TOC, TOX, TOH, O&G, WIDROW, Phenolics, OTHER:	☐Yes ☑No	Initial when completed BF | Lab Std #ID of preservative | Date/ Time:
Headspace in VOA Vials (>6mm):	☐Yes ☐No ☑N/A	14.
Trip Blank Present:	☐Yes ☐No ☑N/A	15.
Trip Blank Custody Seals Present	☐Yes ☐No ☑N/A	
Pace Trip Blank Lot # (if purchased):		

Client Notification/ Resolution: If checked, see attached form for additional comments ☐

Person Contacted: Date/Time:

Comments/ Resolution: Split 001 (1-250mLp^D) into 1-125mLp^A on 6-7-13 at 1355. 6/7/13 BF

Project Manager Review: **Date:** 6-7-13

F-GB-C-031-Rev.01 (01Mar2013) SCUR Form

Attachment E

Edwards Station Coal Ash Leach Testing Results (2008)

Summary of Results from ASTM D3987-85 testing of Edwards Station Coal Combustion By-Products used at Duck Creek Station Wedge area.

		Initial Sampling									Additional Sampling***				
Parameter	Groundwater Standards (mg/L)	Site 1A* (mg/L)	Site 1B (mg/L)	Site 2A (mg/L)	Site 2B (mg/L)	Site 3A (mg/L)	Site 3B (mg/L)	Site 4A (mg/L)	Site 4B (mg/L)	Initial Average concentration of Edwards Station Coal Combustion By Products used for fill (mg/L)**	Site W 01 (mg/L)	Site W 02 (mg/L)	Site W 03 (mg/L)	Site W 04 (mg/L)	Overall Average concentration of Edwards Station Coal Combustion By Products used for fill (mg/L)**
Date Collected		10/12/06	10/12/06	10/12/06	10/12/06	10/12/06	10/12/06	10/12/06	10/12/06		09/05/07	09/05/07	09/05/07	09/05/07	
Report Date		10/18/06	10/18/06	10/18/06	10/18/06	10/18/06	10/18/06	10/18/06	10/18/06		09/21/07	09/21/07	09/21/07	09/21/07	
Test		D3987	D3987	D3987	D3987	D3987	D3987	D3987	D3987		D3987	D3987	D3987	D3987	
Antimony	0.006	0.005	0.004	0.016	0.005	0.005	< 0.003	0.003	< 0.003	0.0055	0.004	< 0.003	< 0.003	< 0.003	0.0048
Arsenic	0.05	0.006	0.002	0.03	0.01	0.007	0.003	0.004	0.003	0.008	0.004	0.002	0.008	0.004	0.007
Barium	2	0.17	0.17	0.14	0.41	0.28	0.28	0.22	0.22	0.24	0.36	0.32	0.22	0.17	0.25
Beryllium	0.004	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001
Boron	2	3.7	2.4	4.3	2	1.8	1.4	3.1	1.5	2.5	4.1	2.1	1.6	2.7	2.6
Cadmium	0.005	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001
Chloride	200	2.3	1.9	1.7	3.1	7	2.9	6	2.8	3.5	1.1	1.1	3.4	3.5	3.1
Chromium	0.1	< 0.004	< 0.004	< 0.004	< 0.004	0.048	0.017	0.036	0.014	0.02	< 0.004	< 0.004	< 0.004	0.012	0.013
Cobalt	1	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.002
Copper	0.65	< 0.003	< 0.003	< 0.003	0.006	0.006	< 0.003	0.005	0.004	0.004	< 0.003	< 0.003	< 0.003	< 0.003	0.004
Fluoride	4	< 0.25	0.37	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	0.27	< 0.25	< 0.25	< 0.25	< 0.25	0.26
Iron	5	< 0.01	< 0.01	< 0.01	< 0.01	0.014	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01
Lead	0.0075	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001
Manganese	0.15	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001
Mercury	0.002	0.0006	0.0004	0.0006	0.0003	0.0006	0.0002	0.0003	< 0.0002	0.0004	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.0003
Nickel	0.1	< 0.005	0.009	< 0.005	< 0.005	0.005	< 0.005	< 0.005	< 0.005	0.006	< 0.005	< 0.005	< 0.005	< 0.005	0.005
Nitrate	10	0.23	0.15	0.1	0.07	0.15	0.07	0.52	0.063	0.2	21	0.14	0.14	0.64	1.94
Phenolics	0.1	0.0069	< 0.005	< 0.005	0.0089	< 0.005	0.0074	< 0.005	< 0.005	0.006	< 0.005	0.0073	0.018	0.013	0.0076
Selenium	0.05	0.014	0.009	0.02	0.023	0.035	0.015	0.022	0.011	0.02	< 0.001	< 0.001	0.002	0.005	0.013
Silver	0.05	0.008	< 0.015	0.13	< 0.005	< 0.005	< 0.005	< 0.005	0.12	0.04	0.013	0.01	0.01	0.008	0.028
Sulfate	400	140	290	50	40	51	39	66	56	91.5	88	68	39	79	83.8
Thallium	0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001
Zinc	5	0.012	0.009	0.011	0.085	0.035	0.006	0.01	0.017	0.02	0.036	0.036	0.015	0.28	0.046

* Sampling Sites identified with an A means that the samples were collected at the surface, while Sites identified with a B means that the samples were collected ~ 1 foot below the surface.

** Average concentrations were determined using the limit of detection as an actual value.

▨ Concentration exceeds Class 1 Groundwater Quality Standard

Attachment F

2010 Soil Borings and Hydraulic Conductivity Tests

TELEPHONE
309-673-2131
TESTS ★ INVESTIGATIONS
ANALYSIS ★ DESIGN ★ EVALUATIONS
CONSULTATION ★ REPORTS ★ INSPECTIONS
ARBITRATION ★ EXPERT WITNESS TESTIMONY
★ ★ ★ ★ ★ ★ ★ ★ ★ ★
SOILS ★ PORTLAND CEMENT CONCRETE
BITUMINOUS CONCRETE ★ STEEL
ASPHALT ★ AGGREGATES ★ EMULSIONS
POZZOLANIC MATERIALS ★ LIME

WHITNEY & ASSOCIATES
INCORPORATED
2406 West Nebraska Avenue
PEORIA, ILLINOIS 61604-3193

TELEFAX
309-673-3050
GEOTECHNICAL ENGINEERING
CONSTRUCTION QUALITY CONTROL
SUBSURFACE EXPLORATIONS
ENVIRONMENTAL INVESTIGATIONS
★ ★ ★ ★ ★ ★ ★ ★ ★ ★
MONITORING WELL INSTALLATIONS
BUILT-UP ROOF INVESTIGATIONS
WELDER CERTIFICATIONS
INSURANCE INVESTIGATIONS

September 13, 2010

Mr. Bret Brown
Ameren Energy Fuels and Services
P. O. Box 66149, MC-611
St. Louis, Missouri 63166-6149

Re: Geotechnical Engineering
Report Of Site Investigation
Ameren Duck Creek Haul Road
Canton, Illinois

Dear Mr. Butler:

Pursuant to your request, our geotechnical engineering firm has performed a subsurface soils investigation at the above referenced project site. Included in this report are the results of our field and laboratory tests as well as a summary of the data which was obtained during this investigation.

This site investigation included the drilling of four (4) exploratory test borings for the fly ash landfill haul road on August 26, 2010 which extended to depths ranging from approximately nine (9) to sixteen (16) feet below the existing surface grades. The locations of the exploratory soil test borings with respect to the site were established by Mr. Charles Henderson with Ameren Energy Fuels and Services and have been referenced to the rail spur / haul road stationing system. The approximate ground surface elevations of the borings, as indicated on the Soil Boring Logs, have been referenced to the U.S.G.S. datum from topographical information provided on the project as-built cross section sheets. The results of this investigation have been summarized on the enclosed Soil Boring Logs which have been analyzed by our geotechnical engineer and which form the basis for the following observations and comments.

The site under investigation consists of the plant rail spur and fly ash haul road between approximate Station Locations 17+00 to 35+00 wherein structural fills were utilized to establish the proposed subgrade elevations. In the areas of the exploratory borings, approximately twenty-one (21) to twenty-four (24) inches of crushed limestone aggregates were penetrated at the existing surface grades.

As may be observed from the enclosed Soil Boring Logs, the depth of the Lean Clay, cohesive soils extended to depths ranging from approximately four and one-half (4.5) to six and one-half (6.5) feet below the existing surface grades in Borings B-1, B-2 and B-3 (Stations 17+00 to 23+50) and to a depth of approximately twelve (12) feet in Boring B-4 near Station 35+00. As the exploratory borings were extended beyond the cohesive soil cap, fly ash structural fills with varying amounts of bottom ash were encountered whereupon the exploratory borings were discontinued by our drill crew personnel.

The consistency of the cohesive soils was visually classified as stiff to very stiff whereas the relative density of the fly ash materials would be considered medium-density. Standard penetration tests, designated as "N" values, ranged from 7 to 15 blows per foot within the materials encountered during the scope of this investigation.

The description of the various materials encountered, as indicated on the Soil Boring Logs, represent the subsurface conditions at the actual boring locations and variations may be anticipated throughout the site. The lines of demarcation represent the approximate boundary between the soil types although the transition may be gradual.

It may also be observed from an inspection of the Soil Boring Logs that ground water was not encountered during the scope of this investigation. The ground water levels in the bore holes were checked after the completion of the drilling operations and after a brief time lapse. These readings and site observations indicate that the ground water level appears to exist at a depth beyond the scope of this investigation.

In addition to the standard split-barrel samples, a few thin wall Shelby tube samples were collected and returned to our materials testing laboratory for permeability or hydraulic conductivity tests of the various materials encountered. The cohesive soils consisted of a Lean Clay soil obtained from Boring B-1; 2' - 4' (Station 17+00; 6' Right) and Boring B-2; 3' - 5' (Station 22+00; 6' Right) which yielded permeability values of 1.84 x 10^{-7} to 3.36 x 10^{-7} cm/sec. Within the fly ash materials collected from Boring B-2; 7' - 9' (Station 22+00; 6' Right) and Boring B-4; 13.5' - 15.5' (Station 35+00; 6' Right), permeability values ranging from 7.56 x 10^{-6} to 2.56 x 10^{-5} cm/sec were recorded. With the exception of the sample from Boring B-4; 2' - 4' (damaged upon sampling and extraction), the remaining samples have not been extracted and are being retained for further analysis if requested.

In conclusion, a brief investigation of the subsurface materials and ground water conditions has been conducted at the site of the Ameren Duck Creek Haul Road near Canton, Illinois. A summary of the existing site conditions has been presented and the results of our laboratory tests have been discussed in some detail.

Should you have any questions or comments whatsoever in regard to this brief geotechnical engineering report, or if any additional information is desired, do not hesitate to contact us at your convenience.

Respectfully submitted,

WHITNEY & ASSOCIATES

JAMES R.
KRUSEMARK
062-059810

(By)
James R. Krusemark, P. E.

DOUGLAS R.
WHITNEY
062-049190

(By)
Douglas R. Whitney, P. E.

JRK/DRW:rma
Enclosures

WHITNEY & ASSOCIATES
INCORPORATED
2406 West Nebraska Avenue
PEORIA, ILLINOIS 61604

BORING LOG

BORING NO. B-01
DATE 08-26-10
W. & A. FILE NO. 5423
SHEET 1 OF 4

PROJECT AMEREN DUCK CREEK HAUL ROAD
LOCATION Canton, Illinois
BORING LOCATION Station 17+00; 6' Right of Centerline
DRILLED BY Fehl
BORING TYPE Hollow Stem Auger
WEATHER CONDITIONS Partly Cloudy & Mild
SOIL CLASSIFICATION SYSTEM U.S.C.S.
SEEPAGE WATER ENCOUNTERED AT ELEVATION None
GROUND SURFACE ELEVATION 614.6
GROUND WATER ELEVATION AT - HRS. -
BORING DISCONTINUED AT ELEVATION 605.6
GROUND WATER ELEVATION AT COMPLETION None

DESCRIPTION	DEPTH IN FEET	SAMPLE TYPE	N	Qp	Qu	Dd	Mc
CRUSHED LIMESTONE							
	22"						
Light Brown And Gray LEAN CLAY - CL	02						
		ST	-	-	-	106.5	19.5
	04						
Dark Gray FLY ASH With Small Amount of Bottom Ash		SS	4 6 7(13)	-	-	-	-
	06						
	08	ST	-	-	-	-	-
EXPLORATORY BORING DISCONTINUED							
	10						
	12						

N - BLOWS DELIVERED PER FOOT BY A 140 LB. HAMMER FALLING 30 INCHES
SS - SPLIT SPOON SAMPLE
ST - SHELBY TUBE SAMPLE
Qp - CALIBRATED PENETROMETER READING - T.S.F.
Qu - UNCONFINED COMPRESSIVE STRENGTH - T.S.F.
Dd - NATURAL DRY DENSITY - P.C.F.
Mc - NATURAL MOISTURE CONTENT - %

WHITNEY & ASSOCIATES
INCORPORATED
2406 West Nebraska Avenue
PEORIA, ILLINOIS 61604

BORING LOG

BORING NO. B-02
DATE 08-26-10
W. & A. FILE NO. 5423
SHEET 2 OF 4
PROJECT AMEREN DUCK CREEK HAUL ROAD
LOCATION Canton, Illinois
BORING LOCATION Station 22+00; 6' Right of Centerline
DRILLED BY Fehl
BORING TYPE Hollow Stem Auger
WEATHER CONDITIONS Partly Cloudy & Mild
SOIL CLASSIFICATION SYSTEM U.S.C.S.
SEEPAGE WATER ENCOUNTERED AT ELEVATION None
GROUND SURFACE ELEVATION 614.7
GROUND WATER ELEVATION AT - HRS. -
BORING DISCONTINUED AT ELEVATION 605.7
GROUND WATER ELEVATION AT COMPLETION None

DESCRIPTION	DEPTH IN FEET	SAMPLE TYPE	N	Qp	Qu	Dd	Mc
CRUSHED LIMESTONE							
	21"						
Light Brown And Gray LEAN CLAY - CL	02						
	04	ST	-	-	-	105.4	18.5
		SS	4 6 7(13)	-	-	-	-
Dark Gray FLY ASH With Some Bottom Ash	06						
	08	ST	-	-	-	77.9	27.7
EXPLORATORY BORING DISCONTINUED							
	10						
	12						

N - BLOWS DELIVERED PER FOOT BY A 140 LB. HAMMER FALLING 30 INCHES
SS - SPLIT SPOON SAMPLE
ST - SHELBY TUBE SAMPLE
Qp - CALIBRATED PENETROMETER READING - T.S.F.
Qu - UNCONFINED COMPRESSIVE STRENGTH - T.S.F.
Dd - NATURAL DRY DENSITY - P.C.F.
Mc - NATURAL MOISTURE CONTENT - %

WHITNEY & ASSOCIATES
INCORPORATED
2406 West Nebraska Avenue
PEORIA, ILLINOIS 61604

BORING LOG

BORING NO. B-03
DATE 08-26-10
W. & A. FILE NO. 5423
SHEET 3 OF 4
PROJECT AMEREN DUCK CREEK HAUL ROAD
LOCATION Canton, Illinois
BORING LOCATION Station 23+50; 6' Right of Centerline
DRILLED BY Fehl
BORING TYPE Hollow Stem Auger
WEATHER CONDITIONS Partly Cloudy & Mild
SOIL CLASSIFICATION SYSTEM U.S.C.S.
SEEPAGE WATER ENCOUNTERED AT ELEVATION None
GROUND SURFACE ELEVATION 614.7
GROUND WATER ELEVATION AT - HRS. -
BORING DISCONTINUED AT ELEVATION 605.7
GROUND WATER ELEVATION AT COMPLETION None

DESCRIPTION	DEPTH IN FEET	SAMPLE TYPE	N	Qp	Qu	Dd	Mc
CRUSHED LIMESTONE							
	24"						
Light Brown LEAN CLAY - CL	02						
		ST	-	-	-	-	-
	04						
		SS	3 3 7(10)	-	-	-	-
	06						
Dark Gray FLY ASH With Small Amount Of Bottom Ash							
	08	ST	-	-	-	-	-
EXPLORATORY BORING DISCONTINUED							
	10						
	12						

N - BLOWS DELIVERED PER FOOT BY A 140 LB. HAMMER FALLING 30 INCHES
SS - SPLIT SPOON SAMPLE
ST - SHELBY TUBE SAMPLE

Qp - CALIBRATED PENETROMETER READING - T.S.F.
Qu - UNCONFINED COMPRESSIVE STRENGTH - T.S.F.
Dd - NATURAL DRY DENSITY - P.C.F.
Mc - NATURAL MOISTURE CONTENT - %

WHITNEY & ASSOCIATES
INCORPORATED
2406 West Nebraska Avenue
PEORIA, ILLINOIS 61604

BORING LOG

BORING NO. B-04
DATE 08-26-10
W. & A. FILE NO. 5423
SHEET 4 OF 4

PROJECT AMEREN DUCK CREEK HAUL ROAD
LOCATION Canton, Illinois
BORING LOCATION Station 35+00; 6' Right of Centerline
DRILLED BY Fehl
BORING TYPE Hollow Stem Auger
WEATHER CONDITIONS Partly Cloudy & Mild
SOIL CLASSIFICATION SYSTEM U.S.C.S.
SEEPAGE WATER ENCOUNTERED AT ELEVATION None
GROUND SURFACE ELEVATION 615.6
GROUND WATER ELEVATION AT - HRS. -
BORING DISCONTINUED AT ELEVATION 600.1
GROUND WATER ELEVATION AT COMPLETION None

DESCRIPTION	DEPTH IN FEET	SAMPLE TYPE	N	Qp	Qu	Dd	Mc
CRUSHED LIMESTONE							
	23"						
Light Brown And Gray-Brown LEAN CLAY With Sand And Some Oversized Crushed Limestone							
	03						
		ST	-	-	-	-	-
Light Brown And Gray LEAN CLAY - CL		SS	3 3 4(7)	-	-	-	-
	06						
		SS	6 7 8(15)	-	-	-	-
	09						
		SS	6 6 8(14)	-	-	-	-
	12	SS	5 6 8(14)	-	-	-	-
Dark Gray FLY ASH With Considerable Bottom Ash							
	15	ST	-	-	-	-	-
EXPLORATORY BORING DISCONTINUED							
	18						

N - BLOWS DELIVERED PER FOOT BY A 140 LB. HAMMER FALLING 30 INCHES
SS - SPLIT SPOON SAMPLE
ST - SHELBY TUBE SAMPLE
Qp - CALIBRATED PENETROMETER READING - T.S.F.
Qu - UNCONFINED COMPRESSIVE STRENGTH - T.S.F.
Dd - NATURAL DRY DENSITY - P.C.F.
Mc - NATURAL MOISTURE CONTENT - %

PERMEABILITY TEST REPORT

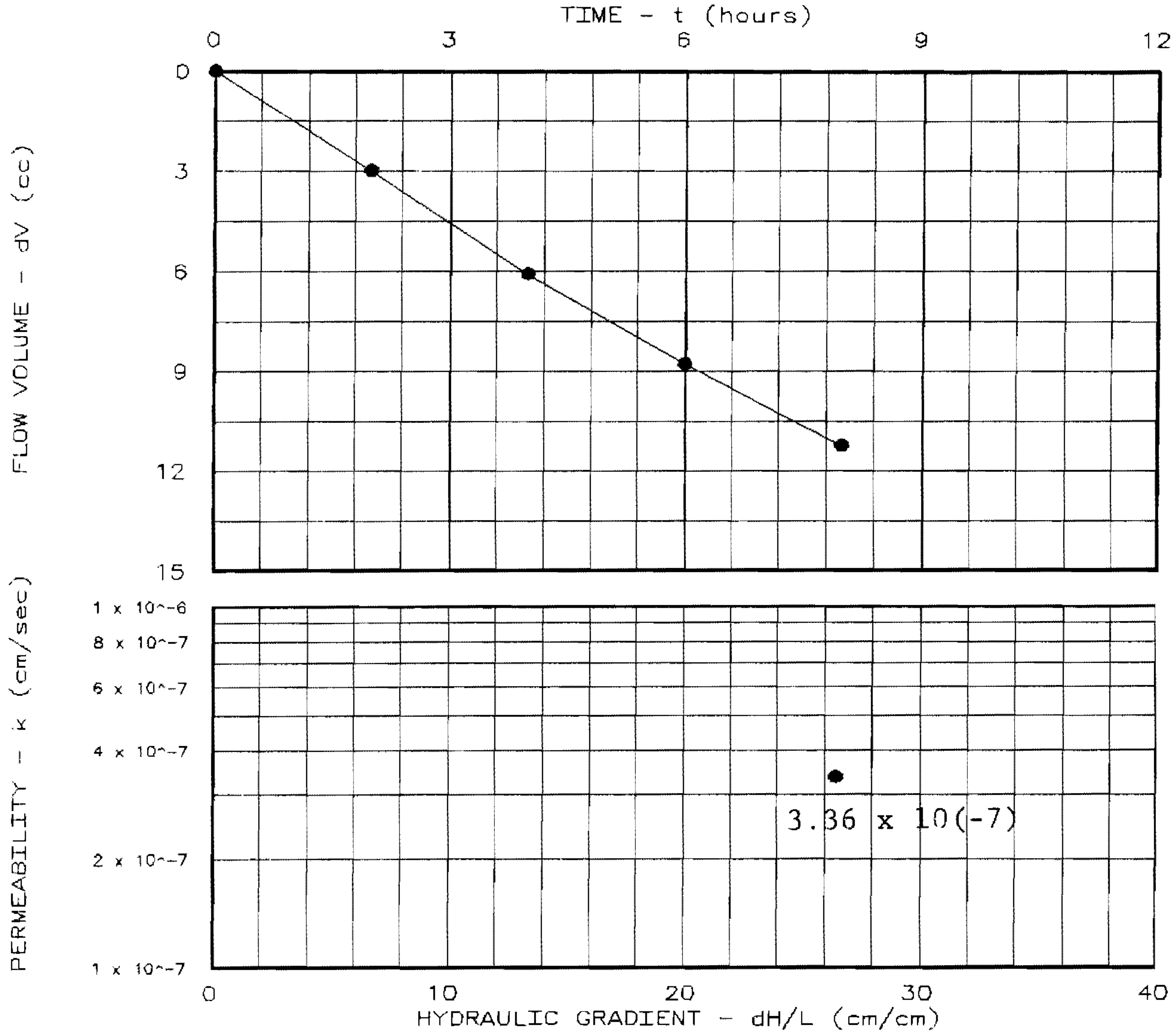
TEST DATA:

Specimen Height (cm): 8.28
Specimen Diameter (cm): 7.24
Dry Unit Weight (pcf): 105.4
Moisture Before Test (%): 18.5
Moisture After Test (%): 22.2
Run Number: 1 ● 2 ▲
Cell Pressure (psi): 9.0
Test Pressure (psi): 6.0
Back Pressure (psi): 2.9
Diff. Head (psi): 3.1
Flow Rate (cc/sec): 3.93 x 10^-4
Perm. (cm/sec): 3.36 x 10^-7

SAMPLE DATA:

Sample Identification: Station 22+00; 6' Right of Centerline (Boring B-2;3'-5')
Visual Description: Light Brown & Gray LEAN CLAY (CL)
Remarks: ASTM D-5084 & IEPA Test Procedures
Maximum Dry Density (pcf): -
Optimum Moisture Content (%): -

Percent Compaction:
Permeameter type: B-K Flexwall
Sample type: 3" S.T.



Project: AMEREN CILCO DUCK CREEK HAUL ROAD
Location: Canton, Illinois
Date: 9-13-10

PERMEABILITY TEST REPORT

WHITNEY & ASSOCIATES

Project No.: ACDC-1
File No.: 1211
Lab No.: 4
Tested by: JRK
Checked by: JRK
Test: CH - Constant head

PERMEABILITY TEST REPORT

TEST DATA:

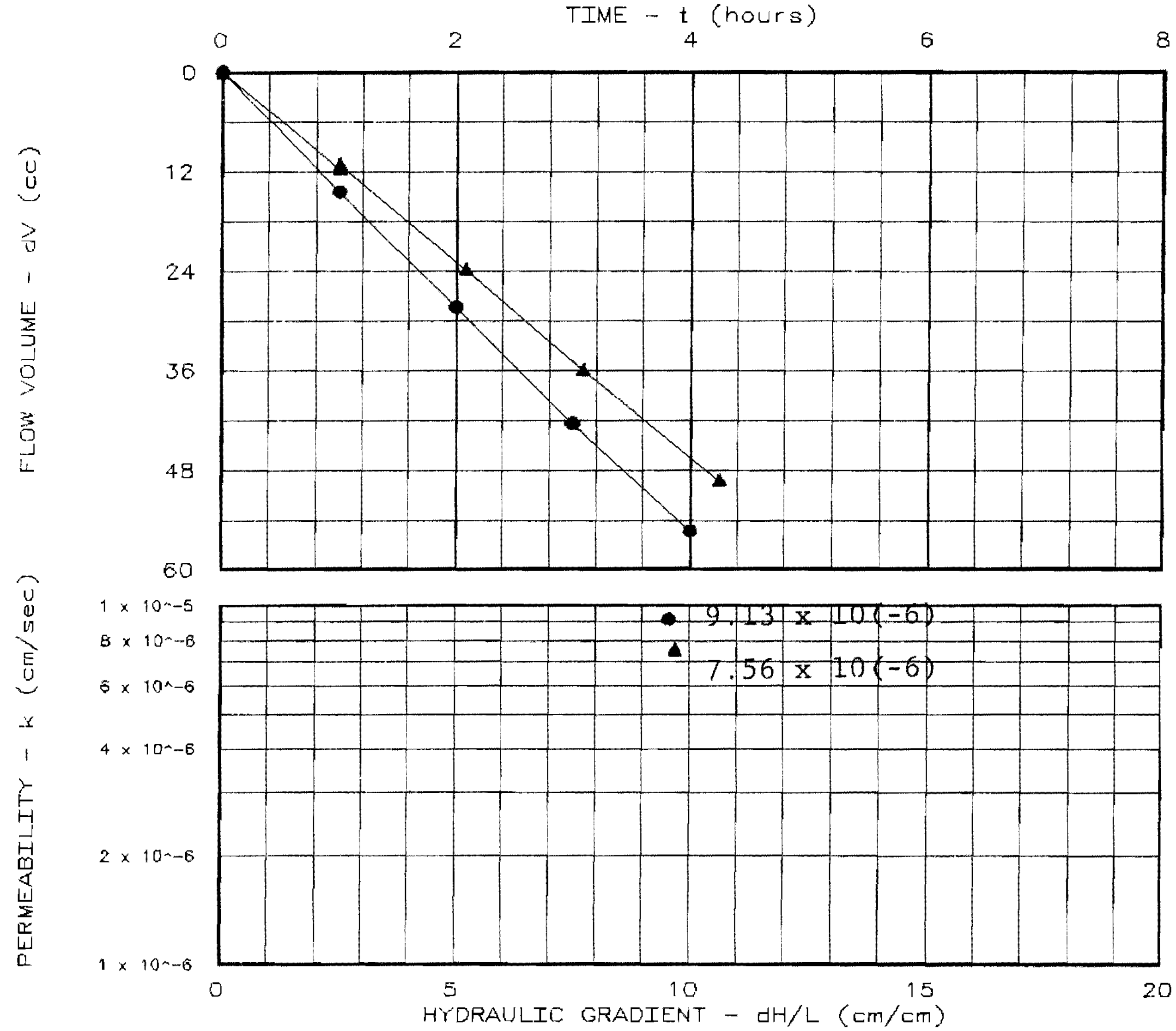
Specimen Height (cm): 7.40
Specimen Diameter (cm): 7.24
Dry Unit Weight (pcf): 77.9
Moisture Before Test (%): 27.7
Moisture After Test (%): 36.5

Run Number:	1 ●	2 ▲
Cell Pressure (psi):	7.0	10.0
Test Pressure (psi):	4.0	4.0
Back Pressure (psi):	3.0	3.0
Diff. Head (psi):	1.0	1.0
Flow Rate (cc/sec):	3.86 x 10^-3	3.24 x 10^-3
Perm. (cm/sec):	9.13 x 10^-6	7.56 x 10^-6

SAMPLE DATA:

Sample Identification: Station 22+00; 6' Right of Centerline (Boring B-2;7'-9')
Visual Description: Dark Gray FLY ASH With Some Bottom Ash
Remarks: ASTM D-5084 & IEPA Test Procedures
Maximum Dry Density (pcf): -
Optimum Moisture Content (%): -

Percent Compaction:
Permeameter type: B-K Flexwall
Sample type: 3" S.T.



Project: AMEREN CILCO DUCK CREEK HAUL ROAD
Location: Canton, Illinois
Date: 9-13-10

PERMEABILITY TEST REPORT

WHITNEY & ASSOCIATES

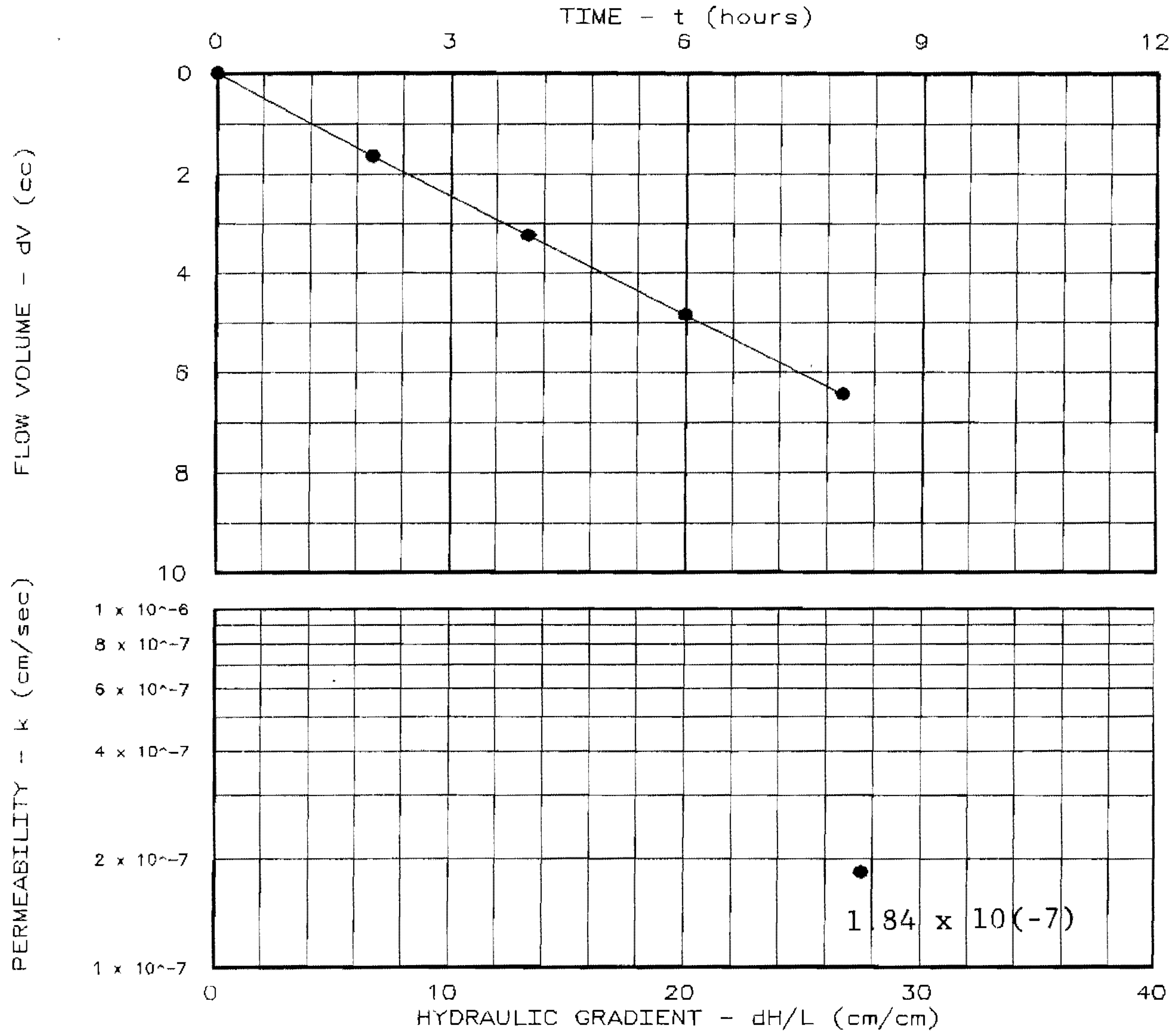
Project No.: ACDC-2
File No.: 1212
Lab No.: 5
Tested by: JRK
Checked by: JRK
Test: CH - Constant head

PERMEABILITY TEST REPORT

TEST DATA:
Specimen Height (cm): 8.05
Specimen Diameter (cm): 7.24
Dry Unit Weight (pcf): 106.5
Moisture Before Test (%): 19.5
Moisture After Test (%): 20.8
Run Number: 1 ● 2 ▲
Cell Pressure (psi): 9.0
Test Pressure (psi): 6.0
Back Pressure (psi): 2.8
Diff. Head (psi): 3.2
Flow Rate (cc/sec): 2.24 x 10^-4
Perm. (cm/sec): 1.84 x 10^-7

SAMPLE DATA:
Sample Identification: Station 17+00; 6' Right of Centerline (Boring B-1;2'-4')
Visual Description: Light Brown & Gray LEAN CLAY (CL)
Remarks: ASTM D-5084 & IEPA Test Procedures
Maximum Dry Density (pcf): -
Optimum Moisture Content (%): -

Percent Compaction:
Permeameter type: B-K Flexwall
Sample type: 3" S.T.



Project: AMEREN CILCO DUCK CREEK HAUL ROAD
Location: Canton, Illinois
Date: 9-13-10

PERMEABILITY TEST REPORT

WHITNEY & ASSOCIATES

Project No.: ACDC-3
File No.: 1213
Lab No.: 1
Tested by: JRK
Checked by: JRK
Test: CH - Constant head

PERMEABILITY TEST REPORT

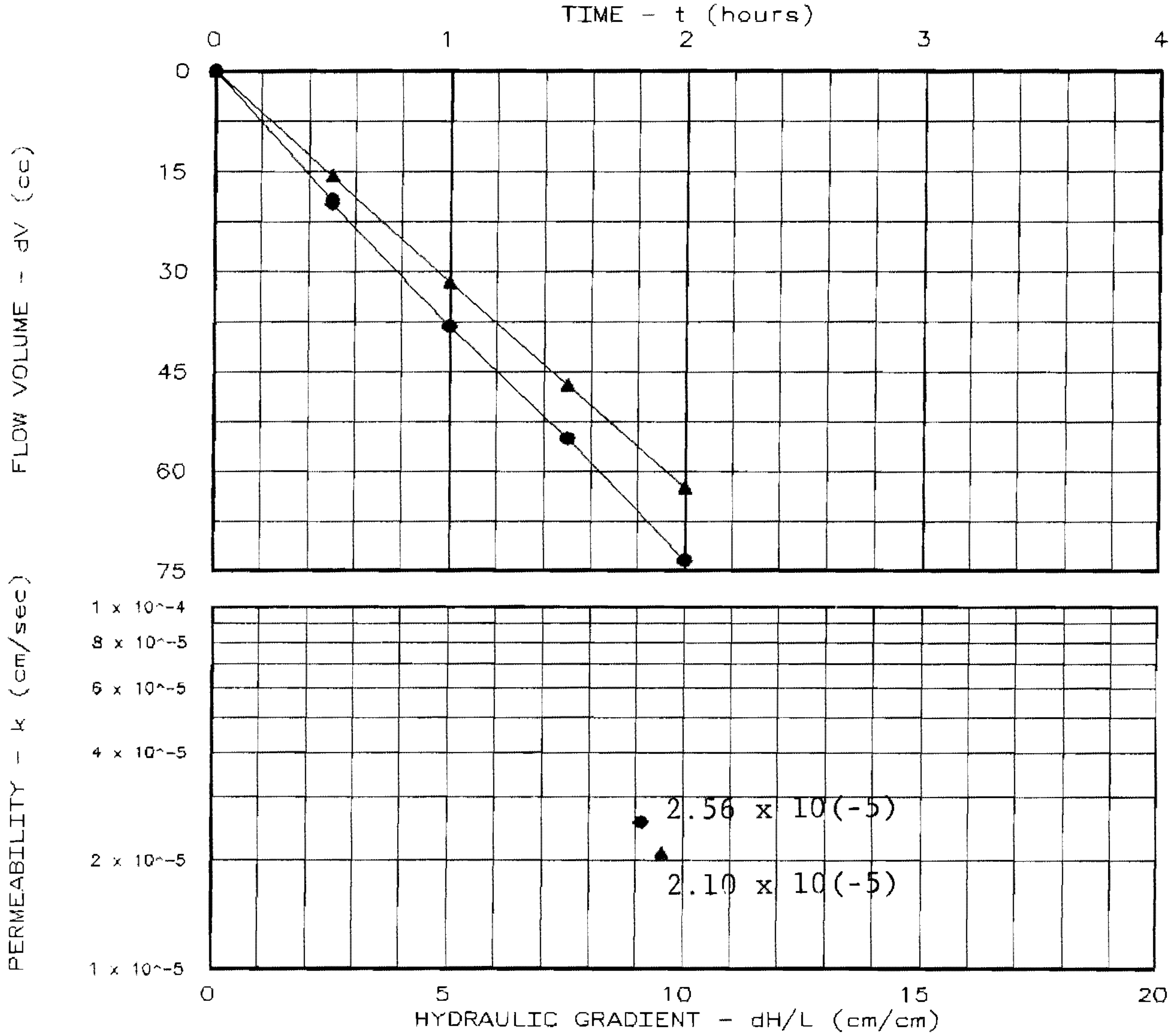
TEST DATA:

Specimen Height (cm): 7.88
Specimen Diameter (cm): 7.17
Dry Unit Weight (pcf): 90.8
Moisture Before Test (%): 20.6
Moisture After Test (%): 24.2

Run Number:	1 ●	2 ▲
Cell Pressure (psi):	7.0	15.0
Test Pressure (psi):	4.0	4.0
Back Pressure (psi):	3.0	2.9
Diff. Head (psi):	1.0	1.1
Flow Rate (cc/sec):	1.01 x 10^-2	8.70 x 10^-3
Perm. (cm/sec):	2.56 x 10^-5	2.10 x 10^-5

SAMPLE DATA:

Sample Identification: Station 35+00; 6' Right of CL(Boring B-4; 13.5'-15.5')
Visual Description: Dark Gray FLY ASH With Considerable Bottom Ash
Remarks: ASTM D-5084 & IEPA Test Procedures
Maximum Dry Density (pcf): -
Optimum Moisture Content (%): -
Percent Compaction:
Permeameter type: B-K Flexwall
Sample type: 3" S.T.



Project: AMEREN CILCO DUCK CREEK HAUL ROAD
Location: Canton, Illinois
Date: 9-13-10

PERMEABILITY TEST REPORT

WHITNEY & ASSOCIATES

Project No.: ACDC-4
File No.: 1214
Lab No.: 2
Tested by: JRK
Checked by: JRK
Test: CH - Constant head