TETRA TECH

TECHNICAL MEMORANDUM

To:	**Steve Clough, Brian Loffman, Andrew Steinberg** **Nevada Environmental Response Trust**
From:	Dan Pastor and Dana Grady, Tetra Tech
Date:	August 29, 2018
Subject:	Treatability/Pilot Study Modification No.3, Revision 1 – Galleria Road Bioremediation Treatability Study Nevada Environmental Response Trust Site, Henderson, Nevada

At the request of the Nevada Environmental Response Trust (NERT), this technical memorandum has been prepared to present Tetra Tech's recommended modification to the scope of work for Phase 1 activities associated with the Galleria Road Bioremediation Treatability Study that are currently in progress. As presented in the approved Galleria Road Bioremediation Treatability Study Work Plan (Work Plan) (Tetra Tech, 2017), a treatability study will be performed to evaluate the feasibility and effectiveness of implementing in-situ bioremediation (ISB) to reduce the contaminant mass flux at the mid-plume containment and mass removal boundary, which has been established as a Remedial Action Objective (RAO) for Operable Unit 2. The location of this treatability study is shown in Figure 1.

As part of Phase 1 of the treatability study, several pre-design field activities have been performed to collect area-specific data to optimize the final treatability study design to reduce perchlorate mass flux across the mid-plume boundary near Galleria Road. The Phase 1 pre-design activities, which included geophysics, installation of soil borings/monitoring wells, groundwater sampling, and aquifer testing, were conducted from April to June 2018. Results from these pre-design field activities have revealed perchlorate contamination in groundwater samples collected from monitoring wells screened within the 60 – 85 foot below ground surface (bgs) interval and the 90 – 110 foot bgs interval. The treatability study conceptual design presented in the Work Plan focused on ISB in the upper portion of the contaminated Upper Muddy Creek formation (UMCf), which was based on site knowledge at the time the Work Plan was prepared. However, observations during the recent Phase 1 pre-design activities in the 90 – 110 foot bgs interval identified both perchlorate concentrations as high as 3,200 micrograms per liter (μg/L) in groundwater and a complex hydrogeologic and geochemical environment. These findings require additional technical evaluation to assess the feasibility of ISB in this deeper, impacted zone of the UMCf. The results obtained from the additional data collection effort described herein will be used to design the Phase 2 field-scale treatability study and will be summarized within the forthcoming Galleria Road Bioremediation Treatability Study Work Plan Addendum.

1.0 PHASE 1 ACTIVITIES TO-DATE

During the on-going Phase 1 pre-design activities, soil borings were advanced to a depth of 120 feet bgs. A pair of monitoring wells was installed at each location to evaluate the horizontal and vertical extent of perchlorate

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concentrations and hydraulic gradient changes with depth within the UMCf throughout the treatability study area to help optimize the design and effectiveness of the treatability study. Because saturated alluvium was not present within the treatability study area, monitoring wells were only installed within the UMCf. In general, the shallow UMCf wells were screened within the 60 – 85 foot bgs interval and the deeper UMCf wells were screened from 90 – 110 feet bgs. Soil boring and well locations within the treatability study area are shown on Figure 2. Table 1 presents well construction details.

During drilling activities, soil samples were collected at approximately 10-foot intervals from the top of the water table to the base of the boring. All soil samples were analyzed for perchlorate. Six soil samples were also analyzed for a suite of analytes to provide additional characterization of the subsurface in accordance with the Work Plan. Tables 2 and 3 present the soil analytical results. Following the completion of well development, groundwater samples were collected from newly installed and existing monitoring wells within the vicinity of the treatability study area and analyzed for a variety of parameters (including perchlorate), in accordance with the Work Plan. Table 4 presents the groundwater analytical results. In addition to elevated perchlorate concentrations as high as 3,200 μg/L, groundwater results also indicate significantly high sulfate and total dissolved solids (TDS) concentrations, up to 34,000 and 64,000 milligrams per liter (mg/L), respectively, in groundwater samples collected from wells screened in the 90 – 110 feet bgs interval. TDS concentrations in this range have previously only been observed in the Unit 4 source area to date. Unlike the Unit 4 source area, the TDS in this area is primarily due to the soil mineralogy rather than chlorate and perchlorate concentrations. TDS concentrations at these levels were unexpected and may cause a lag to the onset of perchlorate biodegradation or may sometimes even hinder perchlorate biodegradation. Understanding the complex geochemistry and its impact on ISB is key to properly evaluating remedial approaches at the mid-plume RAO location for the Feasibility Study.

In addition to soil and groundwater sampling, aquifer testing was performed consisting of slug tests, borehole dilution tests, and nuclear magnetic resonance (NMR) logging. A supporting technical memorandum that includes a summary of field procedures, data analyses, AQTESOLV (HydroSOLVE, 2007) interpretations plots from slug tests, borehole dilution test plots, and NMR logging profiles is provided in Attachment A. Results from the slug tests and borehole dilution tests, which are summarized in Table 1, indicate that the hydraulic conductivity and groundwater flow velocity in the 60 – 85 foot bgs interval of the UMCf were significantly higher than in the wells screened from 90 – 110 feet bgs. NMR estimates of hydraulic conductivity generally agreed with estimates derived using slug testing within an order of magnitude.

Table 1 Aquifer Test Results

Zone	Range of Hydraulic Conductivity (ft/d)	Groundwater Velocity (ft/d)
UMCf (60 – 85 ft bgs)	0.0015 – 1.4	3.4
UMCf (90 – 110 ft bgs)	0.001 – 0.0036	0.0035

Notes:

ft/d – feet per day
UMCf – Upper Muddy Creek formation
ft bgs – feet below ground surface

2.0 RECOMMENDATION

Based on the recent data collected (described in Section 1.0), Tetra Tech recommends modifying the scope of work for the current Phase 1 activities associated with the Galleria Road Bioremediation Treatability Study. As explained in Section 1.0, pre-design activities have focused primarily on two zones, specifically the shallow UMCf from 60 to 85 feet bgs and a deeper interval within the UMCf from 90 to 110 feet bgs. A review of the pre-design results indicates that these two potential treatment intervals vary considerably with respect to the lithological characteristics, groundwater flow patterns and rates, contaminant concentrations, and groundwater geochemistry. Due to these differences, the treatability study objectives and design have been refined to present a design for testing each of the two potential treatment zones. Although a bioremediation treatability study design will be prepared for the 60 – 85 foot bgs interval as planned in the Work Plan, additional information is required to determine if ISB is a feasible approach for the deeper zone (90 to 110 feet bgs). While this Technical Memorandum describes the additional information that Tetra Tech recommends collecting, it should be noted that this work plan modification is not proposing any new additional soil borings or monitoring well installations. Work prescribed in this modification will utilize monitoring wells installed as part of the approved Treatability Study Phase I scope of work.

2.1 Objectives

As presented in the Work Plan, the primary objective of the pre-design activities is to collect key data to design an appropriate field scale treatability study to best address perchlorate migration in the vicinity of the proposed mid-plume RAO boundary. Due to the complexities observed during the Phase 1 pre-design activities, an additional data collection effort in the form of an ISB screening test is warranted to determine the feasibility of implementing this technology within the 90 – 110 feet bgs interval. The primary objectives of the ISB screening testing are to determine the following:

- Evaluate the effectiveness of ISB for this very high sulfate and TDS zone in a laboratory setting using soil and groundwater from 90 – 110 feet bgs.
- Evaluate the practicability of performing injections into the low conductivity 90 – 110 foot bgs treatment interval.

These objectives will be evaluated in laboratory batch microcosm tests and a field injection screening test as described below.

2.2 Laboratory Batch Microcosm Tests

The results from the pre-design groundwater sampling event performed in May 2018 indicate a fairly complex geochemical environment in the 90 – 110 foot bgs interval. As shown in Table 4, perchlorate concentrations in groundwater range from non-detect to 3,200 μg/L, while chlorate concentrations in groundwater range from non-detect to 1,600 μg/L. Nitrate, which is the most likely competing electron acceptor and carbon substrate consumer during perchlorate bioremediation, was not detected. However, as discussed in Section 1.0, sulfate and TDS were detected at concentrations as high as 34,000 and 64,000 mg/L, respectively. Unlike within the Unit 4 area, the high TDS concentrations are due to the high sulfate concentrations and associated cations, rather than due to perchlorate and chlorate concentrations. Sulfate and TDS concentrations at these levels could pose a challenge to the microbial community. Like nitrate, sulfate can also be an electron acceptor and potential carbon substrate consumer during bioremediation processes. As a result, sulfate concentrations at these levels could result in substantial competition in the perchlorate biodegradation process and result in sulfate biodegradation. Sulfate biodegradation is not desirable for the following reasons: 1) it results in unnecessary consumption of carbon substrate; 2) sulfate-reducing microorganisms could overtake perchlorate-reducing microorganisms; 3) hydrogen sulfide would be produced; and 4) hydraulic permeability may be reduced.

Based on the high sulfate and TDS concentrations, ISB in the 90 – 110 foot bgs interval is expected to be more challenging than in the 60 – 85 foot bgs interval. Consequently, laboratory batch microcosm tests are recommended to understand if native microorganisms can successfully overcome the high sulfate and TDS concentrations and proceed to biodegrade perchlorate and chlorate. If successful, the resulting data will be evaluated to estimate potential acclimation time and perchlorate biodegradation rates. The microcosm tests will be performed by the University of Nevada Las Vegas (UNLV) using soil and groundwater from the 90 – 110 foot bgs interval that was recently collected as part of the Phase 1 pre-design activities. The tests are anticipated to last approximately 16 to 20 weeks, depending on the microbial acclimation time, lag time, and kinetics of biodegradation.

These additional laboratory microcosm tests on soil and groundwater from the 90 – 110 foot bgs interval are key to evaluating the potential for ISB application in this more complex environment prior to implementing a field treatability study. Although bench-scale tests are currently being performed for this Treatability Study, these studies only focus on geochemistry typical of the shallow UMCf from 60 – 85 feet bgs. The geochemistry typical of the 90 – 110 feet bgs zone is different from that of the shallower zone and therefore must be evaluated via separate microcosm tests. As a result, these additional microcosm studies will provide essential information to aid in determining whether the UMCf within the 90 – 110 feet bgs zone is amenable to ISB given its geochemical characteristics, which is critical information for evaluating remedial technologies to be implemented within the vicinity of the mid-plume RAO.

2.3 Field Screening Injection Test

The ability to inject carbon substrate-laden fluids into the subsurface is one of the cornerstones of successful ISB application. As a result, the objective of this field screening injection test is to evaluate the practicability of injection into the 90 – 110 foot bgs interval in this study area. Although injections have occurred within similar intervals in other parts of the site, the material here is significantly more consolidated and cemented than has been encountered in the UMCf at other treatability study locations, and the groundwater may be migrating through fractured networks or more transmissive zones within the cemented material. Therefore, injections have not occurred within a similar geological setting of the UMCf to date. This zone has an extremely low hydraulic conductivity (estimated at 0.002 ft/day from slug tests) and, therefore, it is important to examine the engineering viability of injecting fluids prior to embarking on a larger scale field treatability test. To gauge the variability within the subsurface, it is recommended that a screening test be performed consisting of step-rate injection tests in the four newly installed pre-design monitoring wells that are screened from 90 – 110 feet bgs, namely GRTS-MW01B, GRTS-MW02B, GRTS-MW03B, and GRTS-MW04B (shown in Figure 1). Because the monitoring well construction does not differ significantly from the proposed injection well construction, using the monitoring wells installed as part of pre-design activities to assess possible injection rates and effects is appropriate.

For screening purposes, water obtained from a local City of Henderson fire hydrant has been selected as the injectate. Prior to performing the step-rate injection test, an Underground Injection Control permit application will be submitted for permission to inject hydrant water at pressures up to 60 pounds per square inch (psi) in the four monitoring wells. During the field test, step-rate injection tests will be performed to establish potential injection rates and associated pressures in the injection wells and to evaluate the maximum and optimized approach for potential acceptance of water over shorter periods (in minutes) and longer periods (in hours). Specifically, Cascade Technical Services will be subcontracted to perform the step-rate injection tests under Tetra Tech oversight. The step-rate injection tests will be performed by injecting water, typically gradually increasing the pressure in approximately 10 pounds per square inch (psi) increments up to a maximum injection pressure of approximately 60 psi, which is less than the estimated fracture breakthrough pressure (calculations provided in Attachment B). Injections will occur for approximately twenty minutes for each 10 psi increment. Flow rates, total volume, and injection pressures will be monitored and documented throughout the injection process. The wells will be evaluated individually and in tandem to simulate the actual injection protocol that are typically established for actual carbon injections during bioremediation.

In addition to monitoring for injection related parameters at the injection wells, the groundwater response to the injections will also be monitored with pressure transducers. Specifically, transducers will be placed in the paired shallower UMCf monitoring well of the well that is receiving the injections (i.e., GRTS-MW01A, GRTS-MW02A, GRTS-MW03A, or GRTS-MW4A) and the other three remaining similar-completion monitoring wells screened from 90 – 110 feet bgs. A barometric pressure transducer will be used to record barometric pressure during these tests. Manual water level measurements will also be collected from all monitoring wells installed as part of pre-design activities and nearby monitoring wells ES-13 and MCF-06B. Manual water levels will be collected before the start of each test, during each step-rate injection/pressure increase, and during recovery after testing. In addition, a downhole probe suitable for monitoring field parameters such as TDS and conductivity will be used to monitor whether the injected water physically reaches any of the monitoring wells. The downhole probe will be used to collect a baseline set of field parameters immediately prior to testing and near the end of each step. The manual water levels and field parameter measurements will be recorded on field forms and used with the transducer data to determine the area affected by the injections.

The findings of this screening test will be used to determine if the subsurface in the 90 – 110 foot bgs interval can accept injections under increased pressures, which is necessary to understand prior to injections for ISB. Transducer and manual water level data will be evaluated to determine the areal extent of pressure response to injection, and downhole field parameters (TDS or conductivity) will be assessed to determine whether actual injected water entered any of the monitoring wells. Additionally, the resulting injection flow rates achieved coupled with the varying pressures will be used to ascertain if the required and designed amount of carbon-substrate laden water coupled with follow-up distribution water can be introduced at rates that are practical for the performance of the treatability study and for future bioremediation related injection operations. The injection rates and pressure data will also be used to determine the desired and optimal spacing of the injection wells for the treatability study to feasibly introduce carbon-injectate water and distribution water into the formation.

2.4 Evaluation of Results

The results of the batch microcosm testing and field injection screening test will be incorporated into the Galleria Road Bioremediation Treatability Study Work Plan Addendum, which will include details and Trust recommendations on the Phase 2 field aspects of the Treatability Study.

3.0 SCHEDULE

It is anticipated that this field work, including both batch microcosm and step-rate injection testing could take approximately 16 to 20 weeks depending on the microbial acclimation time, lag time, and kinetics of biodegradation observed in the batch microcosm testing. Soil was previously collected from the 90 – 110 feet bgs interval during the Phase 1 drilling activities and transported to UNLV for testing if necessary; therefore, no additional drilling activities are required. As a result, the work recommended in this modification will begin upon NDEP approval and first availability of the injection subcontractor. Every effort will be made to expedite the work described herein and minimize impact to the treatability study project schedule.

4.0 REFERENCES

HydroSOLVE, Inc. (2007). *AQTESOLV* (version 4.50) – Professional. Developed by Glenn M. Duffield

Tetra Tech, Inc. (2017). *Galleria Road Bioremediation Treatability Study Work Plan, Nevada Environmental Respnse Trust Site, Henderson, Nevada.* October 6, 2017.

CERTIFICATION

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been prepared in a manner consistent with the current standards of the profession, and to the best of my knowledge, comply with all applicable federal, state, and local statutes, regulations, and ordinances. I hereby certify that all laboratory analytical data was generated by a laboratory certified by the NDEP for each constituent and media presented herein.

Description of Services Provided: Prepared Treatability/Pilot Study Modification No. 3, Revision 1 – Galleria Road Bioremediation Treatability Study.

Kyle S. Hansen

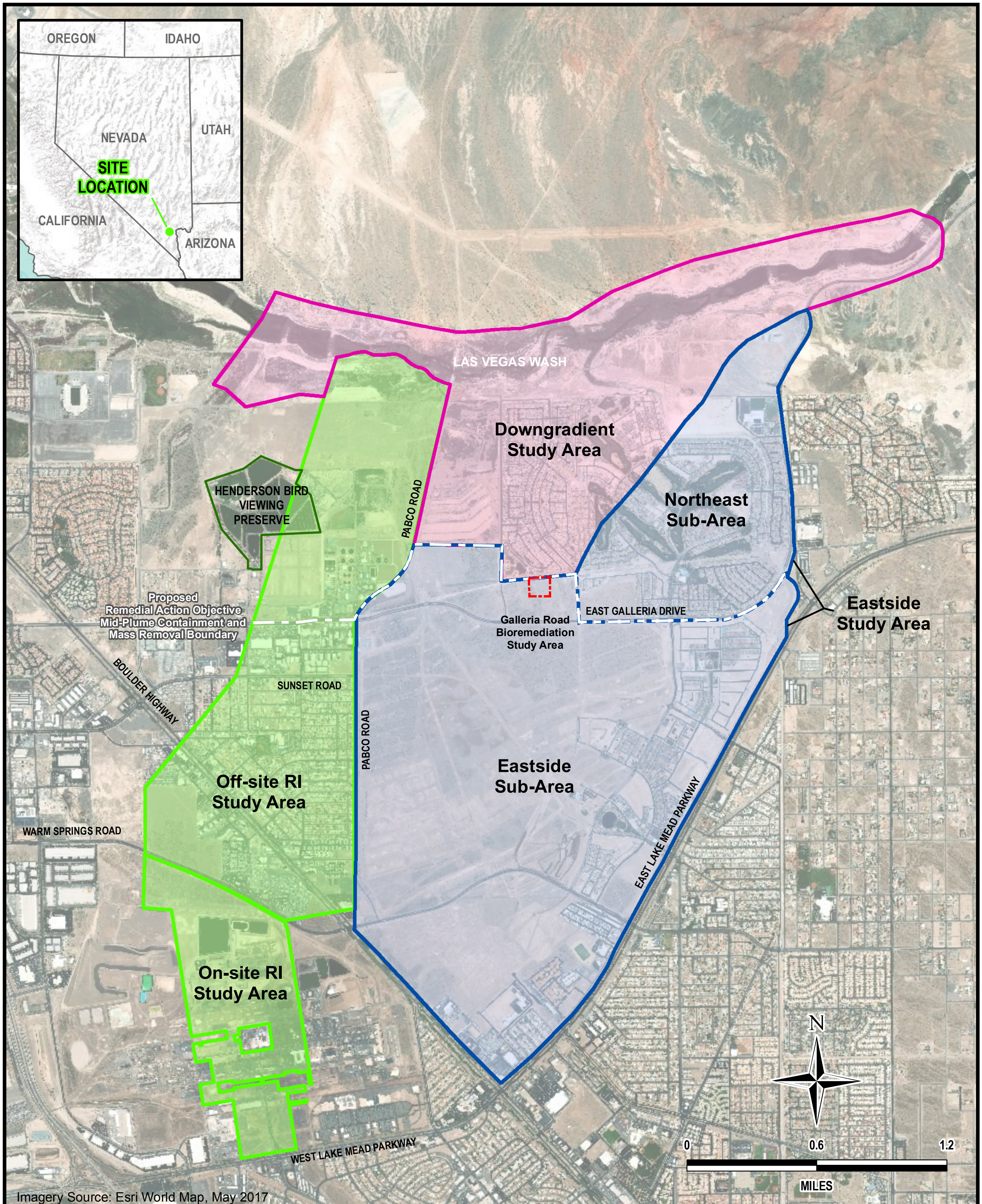
August 29, 2018

Kyle Hansen, CEM
Field Operations Manager/Geologist
Tetra Tech, Inc.

Date

Nevada CEM Certificate Number: 2167
Nevada CEM Expiration Date: September 18, 2020

Figures



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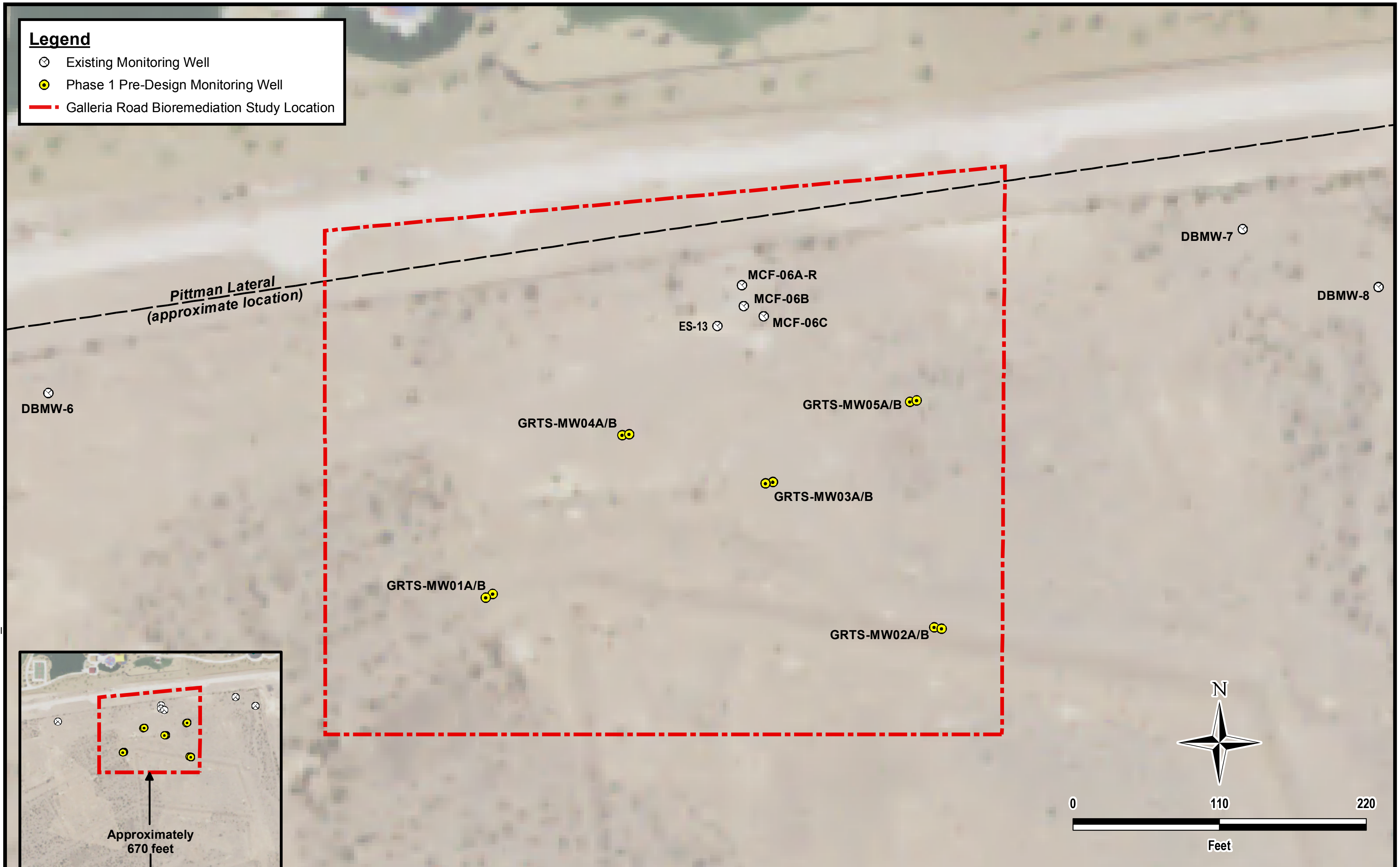
NEVADA ENVIRONMENTAL RESPONSE TRUST

TREATABILITY/PILOT STUDY MODIFICATION NO. 3 -
GALLERIA ROAD BIOREMEDIATION TREATABILITY STUDY

TREATABILITY STUDY LOCATION

Project No.:	117-7502018
Date:	AUGUST 22, 2018
Designed By:	SRA

Figure No.
1



Notes:
1. Imagery Source: Esri World Map, May 2017

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NEVADA ENVIRONMENTAL RESPONSE TRUST

TREATABILITY/PILOT STUDY MODIFICATION NO. 3 -
GALLERIA ROAD BIOREMEDIATION TREATABILITY STUDY

LOCATIONS OF PRE-DESIGN ACTIVITIES

Project No.:	117-7502018
Date:	AUGUST 22, 2018
Designed By:	SRA
Figure No.	2

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Tables

Table 1 Monitoring Well Construction Summary

Monitoring Well/ Borehole ID	Northing	Easting	Ground Surface Elevation	Top of Casing Elevation	Well Diameter	Borehole Diameter	Borehole Total Depth	Well Total Depth	Bottom of Screen	Top of Screen	Screen Length	Slot Size
			feet amsl	feet amsl	inches	inches	feet bgs	feet bgs	feet bgs	feet bgs	feet	inches
GRTS-MW01A	26728794.0	834737.35	1633.882	1633.486	2	6	82	80.5	80	60	20	0.010
GRTS-MW01B	26728796.86	834742.46	1633.883	1633.322	2	6	120	110.5	110	90	20	0.010
GRTS-MW02A	26728771.59	835074.09	1632.586	1632.039	2	6	82	80.5	80	60	20	0.010
GRTS-MW02B	26728770.64	835079.15	1632.432	1631.894	2	6	120	110.5	110	90	20	0.010
GRTS-MW03A	26728879.93	834947.17	1630.720	1630.178	4	8	80	75.5	75	65	10	0.010
GRTS-MW03B	26728880.95	834952.89	1630.548	1630.271	4	8	120	110.5	110	90	20	0.010
GRTS-MW04A	26728915.61	834839.84	1631.086	1630.704	2	6	86.5	85.5	85	70	15	0.010
GRTS-MW04B	26728916.48	834845.04	1631.186	1630.856	2	6	120	110	109.5	89.5	20	0.010
GRTS-MW05A	26728941.0	835055.82	1628.633	1628.193	2	6	80	70.5	70	60	10	0.010
GRTS-MW05B	26728941.82	835060.59	1628.605	1628.231	2	6	120	85.5	85	75	10	0.010

Notes

amsl above mean sea level

bgs below ground surface

Table 2 Soil Analytical Results

Location	Sample Date	QCType	Depth (ft bgs)	Lab SampleID	EPA 314.0	Anions by EPA 300.0 (soluble)			EPA 300.1B	EPA 351.2	SW6010B	SW9060A	SM 2320B (soluble)		SM 2320B (soluble)	SM 2540C (soluble)
					Perchlorate	Chloride (as Cl)	Nitrate (as NO3)	Sulfate	Chlorate	Total Kjeldahl Nitrogen (TKN)	Phosphorus	Total Organic Carbon	Alkalinity as CaCO3	Bicarbonate ion as HCO3	Carbonate (as CO3)	Total Dissolved Solids
					mg/kg	mg/L	mg/L	mg/L	ug/kg	mg/kg	mg/kg	mg/kg	mg/L	mg/L	mg/L	mg/L
GRTS-MW01B	4/19/2018	FD	110 - 110.5	440-209324-6	<0.067	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	70 - 70.5	440-209324-1	2.4	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	80 - 80.5	440-209324-2	<0.065	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	90 - 90.5	440-209324-3	<0.064	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	100 - 100.5	440-209324-4	<0.063 UJ	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	110 - 110.5	440-209324-5	<0.068	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	120 - 120.5	440-209324-7	<0.068	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/13/2018	N	65 - 65.5	440-209035-1	0.52	19	1.3	1,700	2,700 J	11 J	81	<600 UJ	<4.0	<4.8	<2.4	2,400
GRTS-MW02B	4/14/2018	FD	109 - 109.5	440-209035-5	<0.072	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	70 - 70.5	440-209035-2	0.069	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	81 - 81.5	440-209035-3	0.20	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	91 - 91.5	440-209035-6	<0.070	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	92 - 92.5	440-209035-7	<0.070	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	100 - 100.5	440-209035-8	<0.066	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	109 - 109.5	440-209035-4	<0.069	61	<0.25	1,800	<370 UJ	57 J	210	7,900 J	<4.0	<4.8	<2.4	3,400
GRTS-MW02B	4/14/2018	N	120 - 120.5	440-209035-9	<0.066	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	FD	110 - 110.5	440-209880-9	0.076 J	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	63 - 63.5	440-209880-1	0.22	140	<1.3	1,900	<350 UJ	63 J	210	26,000 J	<4.0	<4.8	<2.4	2,600
GRTS-MW03B	4/25/2018	N	73 - 73.5	440-209880-2	0.77	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	83 - 83.5	440-209880-3	<0.061	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	93 - 93.5	440-209880-4	0.75	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	95 - 95.5	440-209880-6	0.29	160	<1.3	1,600	<330 UJ	67 J	700	<600 UJ	<4.0	<4.8	<2.4	2,600
GRTS-MW03B	4/25/2018	N	102 - 102.5	440-209880-5	0.20 J	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	110 - 110.5	440-209880-7	0.072 J	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	120 - 120.5	440-209880-8	<0.080	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	70 - 70.5	440-208822-1	0.57	130	<0.25	610	<330 UJ	88 J	490	1,900 J	<4.0	<4.8	<2.4	1,300
GRTS-MW04B	4/12/2018	N	79 - 79.5	440-208822-2	<0.015	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	90 - 90.5	440-208822-3	<0.066	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	94 - 94.5	440-208822-7	<0.065	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	100 - 100.5	440-208822-4	<0.067	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	110 - 110.5	440-208822-5	<0.077	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	120 - 120.5	440-208822-6	<0.061	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	FD	72 - 72.5	440-209097-6	1.3 J	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	45.5 - 46	440-209097-1	0.56	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	47 - 47.5	440-209097-2	0.68	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	52 - 52.5	440-209097-3	0.60	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	61 - 61.5	440-209097-4	1.2	99	0.36 J	1,900	1,100 J	62 J	180	33,000 J	<4.0	<4.8	<2.4	2,400
GRTS-MW05B	4/17/2018	N	72 - 72.5	440-209097-5	1.7 J	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	82 - 82.5	440-209097-7	<0.065	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	92 - 92.5	440-209097-8	<0.066	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	102 - 102.5	440-209097-9	<0.058	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	111 - 111.5	440-209097-10	<0.064	---	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	120 - 120.5	440-209097-11	<0.013	---	---	---	---	---	---	---	---	---	---	---

Notes

mg/kg	milligrams per kilogram
mg/L	milligrams per liter
ug/L	micrograms per liter
ug/kg	micrograms per kilogram
SU	Standard Units
FD	Field duplicate
N	Normal field sample
<	The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.
J-	The result is an estimated quantity, but the result may be biased low.
J	The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.
J+	The result is an estimated quantity, but the result may be biased high.
UJ	The analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.
--	Not Analyzed

Table 2 Soil Analytical Results

Location	Sample Date	QCType	Depth (ft bgs)	Lab SampleID	SW6010B (soluble)				SW6020 (soluble)				SW7199	SW9045
					Calcium	Magnesium	Potassium	Sodium	Arsenic	Chromium	Iron	Manganese	Chromium, Hexavalent	pH
					mg/L	mg/L	mg/L	mg/L	ug/L	ug/L	ug/L	ug/L	mg/kg	SU
GRTS-MW01B	4/19/2018	FD	110 - 110.5	440-209324-6	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	70 - 70.5	440-209324-1	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	80 - 80.5	440-209324-2	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	90 - 90.5	440-209324-3	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	100 - 100.5	440-209324-4	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	110 - 110.5	440-209324-5	---	---	---	---	---	---	---	---	---	---
GRTS-MW01B	4/19/2018	N	120 - 120.5	440-209324-7	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/13/2018	N	65 - 65.5	440-209035-1	640	24	22	18	7.9	3.1 J	<40	<2.5	<0.24	7.2 J
GRTS-MW02B	4/14/2018	FD	109 - 109.5	440-209035-5	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	70 - 70.5	440-209035-2	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	81 - 81.5	440-209035-3	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	91 - 91.5	440-209035-6	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	92 - 92.5	440-209035-7	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	100 - 100.5	440-209035-8	---	---	---	---	---	---	---	---	---	---
GRTS-MW02B	4/14/2018	N	109 - 109.5	440-209035-4	610	55	230 J	58	7.1	<2.5	<40	6.2	<0.22	7.4 J
GRTS-MW02B	4/14/2018	N	120 - 120.5	440-209035-9	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	FD	110 - 110.5	440-209880-9	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	63 - 63.5	440-209880-1	510	86	98	81	3.8 J	<2.5	<40	<2.5	<0.21	7.6 J
GRTS-MW03B	4/25/2018	N	73 - 73.5	440-209880-2	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	83 - 83.5	440-209880-3	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	93 - 93.5	440-209880-4	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	95 - 95.5	440-209880-6	360	94 J	150 J	110 J	<2.5	2.6 J	<40	13	<0.20	7.8 J
GRTS-MW03B	4/25/2018	N	102 - 102.5	440-209880-5	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	110 - 110.5	440-209880-7	---	---	---	---	---	---	---	---	---	---
GRTS-MW03B	4/25/2018	N	120 - 120.5	440-209880-8	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	70 - 70.5	440-208822-1	33	61	120	88	5.0	<2.5	<40	<2.5	<0.20	7.6 J
GRTS-MW04B	4/12/2018	N	79 - 79.5	440-208822-2	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	90 - 90.5	440-208822-3	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	94 - 94.5	440-208822-7	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	100 - 100.5	440-208822-4	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	110 - 110.5	440-208822-5	---	---	---	---	---	---	---	---	---	---
GRTS-MW04B	4/12/2018	N	120 - 120.5	440-208822-6	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	FD	72 - 72.5	440-209097-6	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	45.5 - 46	440-209097-1	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	47 - 47.5	440-209097-2	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	52 - 52.5	440-209097-3	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	61 - 61.5	440-209097-4	500	70	97	65	<2.5	6.0 J	<40	<2.5	<0.20	7.4 J
GRTS-MW05B	4/17/2018	N	72 - 72.5	440-209097-5	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	82 - 82.5	440-209097-7	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	92 - 92.5	440-209097-8	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	102 - 102.5	440-209097-9	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	111 - 111.5	440-209097-10	---	---	---	---	---	---	---	---	---	---
GRTS-MW05B	4/17/2018	N	120 - 120.5	440-209097-11	---	---	---	---	---	---	---	---	---	---

Notes

mg/kg	milligrams per kilogram
mg/L	milligrams per liter
ug/L	micrograms per liter
ug/kg	micrograms per kilogram
SU	Standard Units
FD	Field duplicate
N	Normal field sample
<	The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.
J-	The result is an estimated quantity, but the result may be biased low.
J	The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.
J+	The result is an estimated quantity, but the result may be biased high.
UJ	The analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.
--	Not Analyzed

Table 3 Soil Microbial Results

Location	Sample Date	Depth (ft bgs)	Sample Matrix	Microbial Census	Microbial Phospholipid Fatty Acid Analysis (PLFA)								
				Perchlorate reductase gene (pcrA)	Total Biomass	Proteobacteria (Monos)	Firmicutes (TerBrSats)	Anaerobic metal reducers (BrMonos)	SRB/Actinomycetes (MidBrSats)	General (Nsats)	Eukaryotes (polyenoics)	Slowed Growth	Decreased Permeability
				cells/gram	cells/gram	%	%	%	%	%	%	ratio cy/cis	ratio trans/cis
GRTS-MW01B	4/19/2018	75-75.5	Soil	<1.67E+04 (I)	3.22E+05	19.71	5.25	0	0	68.17	6.88	1.95	0
GRTS-MW03B	4/26/2018	63-63.5	Soil	<1.67E+04 (I)	4.74E+05	10.80	14.03	0	2.37	69.80	3.01	0	0

Notes

Monos	Monoenoic
TerBrSats	Terminally Branched Saturated
BrMonos	Branched Monoenoic
MidBrSats	Mid-Chain Branched Saturated
Nsats	Normal Saturated
<	Not detected
(I)	Inhibited

Table 4 Groundwater Analytical Results

Location	Screened Interval (ft bgs)	Sample Date	QCType	Lab SampleID	EPA 314.0	Anions by EPA 300.0				EPA 300.1	EPA 351.2	EPA 365.3	Field Tests						Field Tests		NTOTAL	RSK175
					Perchlorate	Chloride (as Cl)	Nitrate (as N)	Nitrite (as N)	Sulfate	Chlorate	Total Kjeldahl Nitrogen (TKN)	Phosphorus	Dissolved Oxygen	Ferrous Iron	Oxidation-Reduction Potential	pH	Specific Conductivity	Sulfide	Temperature	Turbidity	Nitrogen, Total	Methane
					ug/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	mg/L	mg/L	mV	SU	mS/cm	mg/L	C	NTU	mg/L	mg/L
ES-13	90 - 105	5/9/2018	N	440-210948-5	2,800	8,100	<5.5	<7.0	26,000	1,600	<0.10	0.080	2.01	0.0	-58	7.71	47.5	0.0	28.6	2.8	<0.11	<0.00025
GRTS-MW01A	60 - 80	5/10/2018	N	440-211094-3	14,000	5,300	22	<7.0	11,000	19,000	<0.10	0.087	0.42	0.0	47.9	7.75	26.05	0.0	29.41	25.5	22	<0.00025
GRTS-MW01B	90 - 110	5/10/2018	N	440-211094-4	3,200	12,000	<5.5	<7.0	34,000	<250	4.3	0.68	0.30	0.0	113	8.10	50.9	0.0	35.47	102	4.3	0.0015
GRTS-MW02A	60 - 80	5/10/2018	N	440-211094-1	5,600	3,200	24	<3.5	7,000	8,200	0.42	0.16	4.92	0.0	48.8	7.86	18.13	0.0	30.82	119	24	<0.00025
GRTS-MW02B	90 - 110	5/10/2018	N	440-211094-2	<50	8,100	<5.5	<7.0	30,000	<250	3.6	0.90	7.45	0.0	150	8.19	43.5	0.0	28.22	550	3.6	<0.00025
GRTS-MW03A	65 - 75	5/7/2018	FD	440-210696-3	5,700	1,700	37	<1.4	3,400	12,000	<0.10	<0.025	---	---	---	---	---	---	---	---	37	<0.00025
GRTS-MW03A	65 - 75	5/7/2018	N	440-210696-2	5,600	1,700	38	<1.4	3,500	12,000	<0.10	<0.025	2.31	0.0	-10.2	7.82	12.36	0.0	30.44	5.75	38	<0.00025
GRTS-MW03B	90 - 110	5/7/2018	N	440-210696-1	1,700	8,500	<5.5	<7.0	27,000	150 J	0.38	<0.025	3.29	0.0	162	8.10	45.7	0.0	34.88	8.3	0.38	<0.00025
GRTS-MW04A	70 - 85	5/8/2018	N	440-210833-1	8,800	7,300	5.8 J	<7.0	18,000	10,000	<0.10	0.089	0.79	0.0	90.3	7.66	43.80	0.0	28.70	27.3	5.8	<0.00025 UJ
GRTS-MW04B	89.5 - 109.5	5/8/2018	N	440-210833-2	<50	10,000	<5.5	<7.0	31,000	<100	2.1	0.28	0.50	0.0	131	7.87	78.2	0.0	35.19	10.3	2.1	0.0016
GRTS-MW05A	60 - 70	5/9/2018	N	440-210948-1	8,000	2,000	36	<3.5	4,000	13,000	R	0.059	5.26	0.0	141	8.22	12.5	0.0	30.61	19.3	36	<0.00025
GRTS-MW05B	75 - 85	5/9/2018	N	440-210948-2	6,800	6,000	5.8 J	<7.0	18,000	9,600	0.27	0.14	2.61	0.0	60.2	7.92	38.1	0.0	27.34	26.4	6.1	0.0014
MCF-06B	67 - 82	5/9/2018	N	440-210948-4	3,300	6,500	<5.5	<7.0	19,000	3,700	<0.10	0.11	1.34	0.0	55.6	6.79	47.43	0.0	30.46	0.66	<0.11	<0.00025
MCF-06C	44 - 59	5/8/2018	N	440-210833-3	7,100	1,600	43	<1.4	2,800	11,000	<0.10	0.047 J	2.75	0.0	153	7.59	13.9	0.0	29.67	46.7	43	<0.00025

Notes

ug/L	micrograms per liter	SU
mg/L	milligrams per liter	mS/cm
mV	milliVolts	C
FD	Field duplicate	NTU
N	Normal field sample	
<	The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.	
J-	The result is an estimated quantity, but the result may be biased low.	
J	The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.	
UJ	The analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.	
R	The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.	

Table 4 Groundwater Analytical Results

Location	Screened Interval (ft bgs)	Sample Date	QCType	Lab SampleID	SM 2320B	SM 2320B	SM 2320B	SM 2320B	SM 2540C	SM 5310B	Dissolved Metals by SW6010B					Dissolved Metals by SW6010B							Total Manganese by SW6010B	Dissolved Manganese by SW6010B
					Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Hydroxide Alkalinity as CaCO3	Total Dissolved Solids	Total Organic Carbon	Aluminum	Barium	Beryllium	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium		
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ES-13	90 - 105	5/9/2018	N	440-210948-5	87	87	<4.0	<4.0	54,000	1.8	<0.50	<0.050	<0.010	10	<0.025	570	<0.025	<0.050	<0.050	<0.50	<0.038	5,100	<0.15	<0.15
GRTS-MW01A	60 - 80	5/10/2018	N	440-211094-3	78	78	<4.0	<4.0	27,000	1.9	<0.50	<0.050	<0.010	5.2	<0.025	520	0.085	<0.050	<0.050	<0.50	<0.038	1,900	<0.15	<0.15
GRTS-MW01B	90 - 110	5/10/2018	N	440-211094-4	100	100	<4.0	<4.0	64,000	3.4	0.53 J	<0.050	<0.010	9.6	<0.025	550	<0.025	<0.050	<0.050	0.52 J	<0.076	6,100	0.36	0.24
GRTS-MW02A	60 - 80	5/10/2018	N	440-211094-1	75	75	<4.0	<4.0	17,000	2.4	0.50 J	0.056 J	<0.010	4.2	<0.025	590	0.036 J	<0.050	<0.050	0.55 J	<0.038	1,200	0.12	<0.15
GRTS-MW02B	90 - 110	5/10/2018	N	440-211094-2	99	99	<4.0	<4.0	50,000	4.6	3.5	0.073 J	<0.010	9.0	<0.025	520	<0.025	<0.050	<0.050	3.7	<0.038	5,400	0.64	0.46
GRTS-MW03A	65 - 75	5/7/2018	FD	440-210696-3	78	78	<4.0	<4.0	8,600	2.2	<0.50	<0.050	<0.010	3.0	<0.025	670	0.11	<0.050	<0.050	<0.50	<0.038	570	<0.075	<0.15
GRTS-MW03A	65 - 75	5/7/2018	N	440-210696-2	78	78	<4.0	<4.0	8,600	1.9	<0.50	<0.050	<0.010	2.8	<0.025	640	0.11	<0.050	<0.050	<0.50	<0.038	540	<0.075	<0.15
GRTS-MW03B	90 - 110	5/7/2018	N	440-210696-1	95	95	<4.0	<4.0	50,000	4.1	<1.3	<0.13	<0.025	9.7	<0.063	570	<0.063	<0.13	<0.13	<1.3	<0.095	5,600	0.46 J	0.40 J
GRTS-MW04A	70 - 85	5/8/2018	N	440-210833-1	89	89	<4.0	<4.0	39,000	1.2	<0.50	<0.050	<0.010	8.6	<0.025	590	0.050	<0.050	<0.050	<0.50	<0.038	3,700	<0.15	<0.15
GRTS-MW04B	89.5 - 109.5	5/8/2018	N	440-210833-2	100	100	<4.0	<4.0	60,000	3.8	<0.50	<0.050	<0.010	11	<0.025	610	<0.025	<0.050	<0.050	<0.50	<0.038	6,300	0.36	0.34
GRTS-MW05A	60 - 70	5/9/2018	N	440-210948-1	66	66	<4.0	<4.0	11,000	1.9	<0.10	0.030	<0.0020	3.3	<0.0050	660	0.085	<0.010	0.020	<0.10	<0.0076	700	<0.030	<0.030
GRTS-MW05B	75 - 85	5/9/2018	N	440-210948-2	99	99	<4.0	<4.0	38,000	2.8	<0.50	<0.050	<0.010	8.1	<0.025	570	<0.025	<0.050	<0.050	<0.50	<0.038	4,000	<0.15	<0.15
MCF-06B	67 - 82	5/9/2018	N	440-210948-4	71	71	<4.0	<4.0	43,000	1.1	<0.50	<0.050	<0.010	7.3	<0.025	560	<0.025	<0.050	0.052 J	<0.50	<0.038	4,300	<0.15	<0.15
MCF-06C	44 - 59	5/8/2018	N	440-210833-3	69	69	<4.0	<4.0	7,600	1.6	<0.50	<0.050	<0.010	2.6	<0.025	730	0.091	<0.050	<0.050	<0.50	<0.038	460	<0.075	<0.15

Notes

ug/L	micrograms per liter	SU
mg/L	milligrams per liter	mS/cm
mV	milliVolts	C
FD	Field duplicate	NTU
N	Normal field sample	
<	The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.	
J-	The result is an estimated quantity, but the result may be biased low.	
J	The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.	
UJ	The analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.	
R	The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.	

Treatability/Pilot Study Modification No. 3 - Galleria Road Bioremediation Treatability Study

Table 4 Groundwater Analytical Results

Location	Screened Interval (ft bgs)	Sample Date	QCType	Lab SampleID	Dissolved Metals by SW6010B									Dissolved Metals by SW6010B				Dissolved Metals by SW6020				SW7199	VFA-IC					
					Molybdenum	Nickel	Phosphorus	Potassium	Silicon	Silver	Sodium	Strontium	Tin	Titanium	Tungsten	Vanadium	Zinc	Antimony	Arsenic	Selenium	Thallium	Chromium, Hexavalent	Acetic Acid	Butyric Acid	Formic Acid	Lactic Acid	Propionic Acid	Pyruvic Acid
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ES-13	90 - 105	5/9/2018	N	440-210948-5	5.4	<0.050	<1.0	6,400	4.7	<0.050	6,500	11	<0.50	<0.025	<0.50	<0.050	<0.12	<10	<10	50	<10	<0.25	<2.9	<2.6	<2.6	<3.1	<3.5	<19
GRTS-MW01A	60 - 80	5/10/2018	N	440-211094-3	1.2	<0.050	<1.0	2,100	12	<0.050	2,600	10	<0.50	<0.025	<0.50	<0.050	<0.12	<10	19 J	360	13 J	79	<2.9	<2.6	<2.6	<3.1	<3.5	<37
GRTS-MW01B	90 - 110	5/10/2018	N	440-211094-4	4.3	<0.050	<1.0	5,200	7.6	<0.050	6,600	11	<0.50	<0.025	<0.50	<0.050	<0.12	<10	13 J	18 J	<10	<0.25	<2.9	<2.6	<2.6	<3.1	<3.5	<19
GRTS-MW02A	60 - 80	5/10/2018	N	440-211094-1	3.3	<0.050	<1.0	1,400	12	<0.050	1,600	11	<0.50	<0.025	<0.50	<0.050	<0.12	<10	<10	43	<10	25	<2.9	<2.6	<2.6	<3.1	<3.5	<37
GRTS-MW02B	90 - 110	5/10/2018	N	440-211094-2	1.6	<0.050	<1.0	4,300	19	<0.050	4,800	12	<0.50	0.14	<0.50	<0.050	<0.12	<10	<10	<10	<10	<0.25	<2.9	<2.6	<2.6	<3.1	<3.5	<19
GRTS-MW03A	65 - 75	5/7/2018	FD	440-210696-3	0.55	<0.050	<1.0	560	19	<0.050	970	13	<0.50	<0.025	<0.50	<0.050	<0.12	<10	31	40	<10	89	<2.9	<2.6	<2.6	<3.1	<3.5	<3.7
GRTS-MW03A	65 - 75	5/7/2018	N	440-210696-2	0.51	<0.050	<1.0	540	19	<0.050	930	12	<0.50	<0.025	<0.50	<0.050	<0.12	<10	30	54	<10	89	<2.9	<2.6	<2.6	<3.1	<3.5	<3.7
GRTS-MW03B	90 - 110	5/7/2018	N	440-210696-1	1.8	<0.13	<2.5	5,200	5.1	<0.13	5,300	13	<1.3	<0.063	<1.3	<0.13	<0.30 UJ	18 J	12 J	24 J	<10	<0.25	<2.9	<2.6	<2.6	<3.1	<3.5	<74 UJ
GRTS-MW04A	70 - 85	5/8/2018	N	440-210833-1	4.4	<0.050	<1.0	3,900	6.0	<0.050	4,700	12	<0.50	<0.025	<0.50	<0.050	<0.12	<10	22	170 J-	<10	42	<2.9 UJ	<2.6 UJ	<2.6 UJ	<3.1 UJ	<3.5 UJ	<74 UJ
GRTS-MW04B	89.5 - 109.5	5/8/2018	N	440-210833-2	1.3	<0.050	<1.0	6,000	5.0	<0.050	7,600	13	<0.50	<0.025	<0.50	<0.050	<0.12	<10	<10	<10	<10	<0.25	<2.9	<2.6	<2.6	<3.1	<3.5	<74
GRTS-MW05A	60 - 70	5/9/2018	N	440-210948-1	0.87	<0.010	<0.20	950	15	<0.010	1,200	12	<0.10	<0.0050	<0.10	<0.010	<0.024	<10	16 J	48	<10	75	<5.8	<5.2	<5.2	<6.2	<7.0	<7.4 UJ
GRTS-MW05B	75 - 85	5/9/2018	N	440-210948-2	5.0	<0.050	<1.0	4,600	6.6	<0.050	4,300	11	<0.50	<0.025	<0.50	<0.050	<0.12	<10	<10	41	<10	12	<5.8	<5.2	<5.2	<6.2	<7.0	<37
MCF-06B	67 - 82	5/9/2018	N	440-210948-4	2.4	<0.050	<1.0	5,000	2.6	<0.050	4,800	9.9	<0.50	<0.025	<0.50	<0.050	<0.12	<10	<10	91	<10	<0.25	<2.9	<2.6	<2.6	<3.1	<3.5	<19
MCF-06C	44 - 59	5/8/2018	N	440-210833-3	0.36	<0.050	<1.0	380	26	<0.050	880	14	<0.50	<0.025	<0.50	<0.050	<0.12	<10	50	44	<10	70	<2.9	<2.6	<2.6	<3.1	<3.5	<3.7

Notes

ug/L	micrograms per liter	SU
mg/L	milligrams per liter	mS/cm
mV	milliVolts	C
FD	Field duplicate	NTU
N	Normal field sample	
<	The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.	
J-	The result is an estimated quantity, but the result may be biased low.	
J	The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.	
UJ	The analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.	
R	The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.	

Attachment A
Aquifer Parameter Evaluation

TECHNICAL MEMORANDUM

To:	**Dana Grady and Ronnie Britto, Tetra Tech**
From:	Sonya Cadle, Audrey Crockett, and Ellyn Swenson, Tetra Tech
Date:	July 5, 2018
Subject:	Aquifer Parameter Evaluation – Galleria Road Bioremediation Treatability Study

INTRODUCTION

This technical memorandum presents the results of the aquifer slug testing, point dilution testing, and nuclear magnetic resonance logging (NMR) performed as part of the hydrogeological evaluation for the Galleria Road Bioremediation Treatability Study (GRTS) conducted by Tetra Tech, Inc. (Tetra Tech) on behalf of the Nevada Environmental Response Trust (NERT or Trust).

The locations of the wells are shown in ***Figure 1***. The objective of the slug and point dilution tests was to estimate aquifer hydraulic conductivity (K) and groundwater flow velocity in the study area. The objective of the downhole NMR surveys was to estimate hydraulic conductivity of the formation outside of the cased portion of the wells, water content, and the mobile versus less mobile components of porosity to further delineate any localized preferential flow pathways within the treatability study area.

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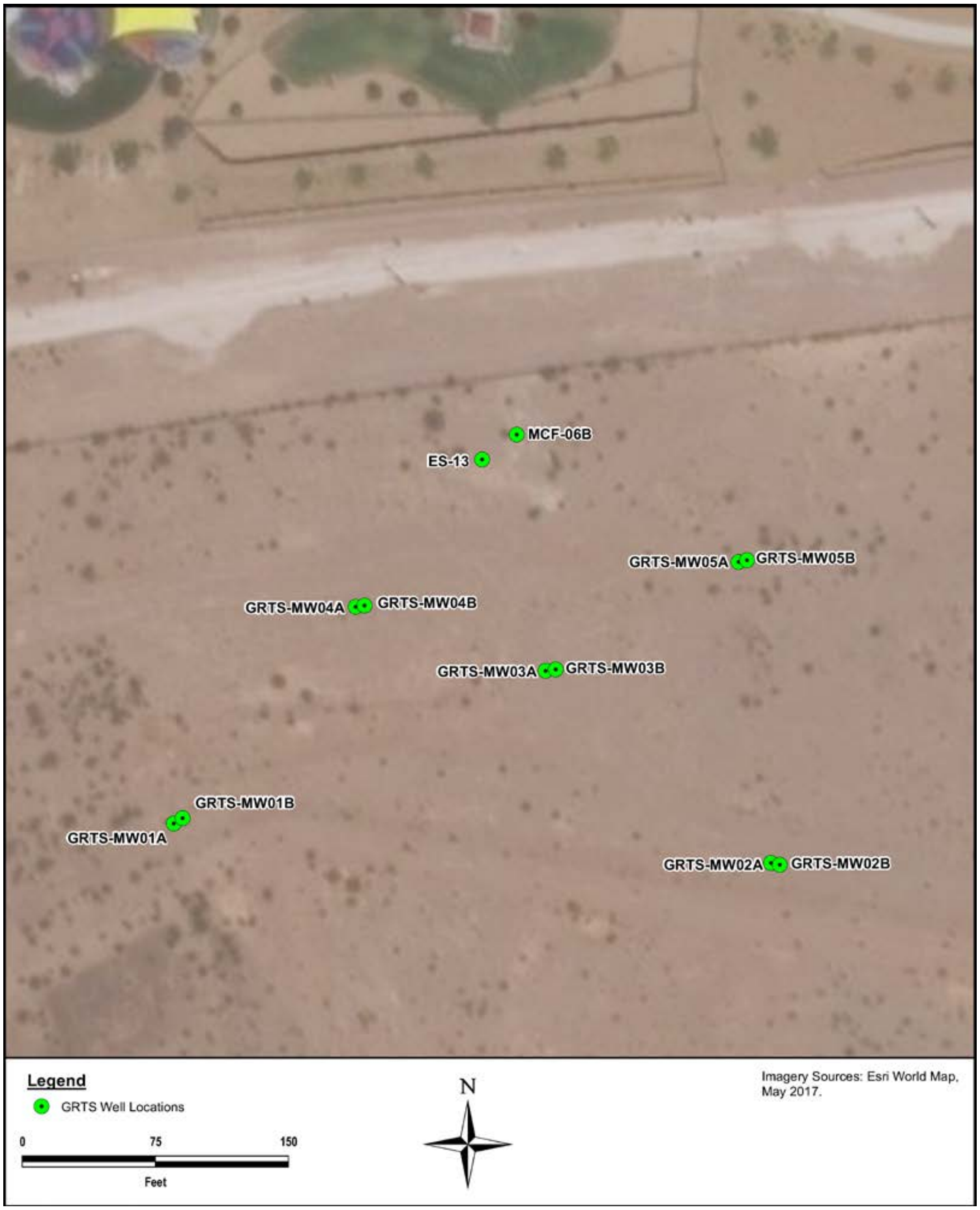

Figure 1 **Location of monitoring wells tested as part of the hydrogeologic evaluation**

SLUG TESTS

Slug testing was performed in May 2018. Well construction information is provided in ***Table 1***. The tests consisted of monitoring water level displacements caused by the insertion or removal of a solid slug from a well. Water level displacement was measured using an In-Situ Rugged TROLL 100 pressure transducer, which was programmed to collect data at one, fifteen, or sixty second time intervals, depending on the well's recovery rate. The size of the slug was selected to be consistent with the diameter of the well, as shown in ***Table 1***.

Table 1 Well Construction Information

Well	UMCf Contact (feet bgs)	Screened Interval (feet bgs)	Top of Casing (feet amsl)	Well Diameter (inches)	Slug Dimensions	
					Diameter (inches)	Length (feet)
GRTS-MW01A	27	60 - 80	1633.49	2	1.25	5
GRTS-MW01B	27	90 - 110	1633.32	2	1.25	5
GRTS-MW02A	36	60 - 80	1632.04	2	1.25	5
GRTS-MW02B	36	90 - 110	1631.89	2	1.25	5
GRTS-MW03A	43.5	65 - 75	1630.18	4	3.00	5
GRTS-MW03B	43.5	90 - 110	1630.27	4	3.00	5
GRTS-MW04A	36	70 - 85	1630.70	2	1.25	5
GRTS-MW04B	36	89.5 - 109.5	1630.86	2	1.25	5
GRTS-MW05A	39	60 - 70	1628.19	2	1.25	5
GRTS-MW05B	39	75 - 85	1628.23	2	1.25	5
ES-13	42	90 - 105	1632.52	4	1.25*	5
MCF-06B	43	90 - 105	1633.06	4	1.25*	5

Notes:

UMCf - Upper Muddy Creek Formation
bgs - below ground surface
amsl - above mean sea level
* - A smaller diameter slug was used due to apparent casing damage.

The slug test data were downloaded from the transducer and the drawdown was calculated from the downloaded data. Slug test analysis was performed using the commercially-available AQTESOLV software (HydroSOLVE 2007). The Bouwer and Rice (1976) method for analyzing slug tests in an unconfined aquifer was used to estimate hydraulic conductivity. The AQTESOLV interpretation plots are provided as Attachment A.1. ***Table 2*** summarizes the results of the slug test analysis; the K values provided for each well represent a mean of the K estimates obtained from individual tests at that well. Water levels measured during the testing events are summarized in ***Table 3***.

All tested wells were screened in the Upper Muddy Creek Formation (UMCf). The estimated Ks are generally consistent with the logged lithology of the screened interval of the wells, which was primarily silt and clay with varying degrees of cementation and compaction. The estimates from the GRTS area slug tests ranged from approximately 0.001 to 1.4 feet per day (ft/day). The hydraulic conductivity decreased with depth such that the UMCf (60-85 ft bgs) wells had hydraulic conductivities up to three orders of magnitude higher than the UMCf (90-110 ft bgs) wells.

Many factors can affect slug test results. Some factors determine whether the K from a slug test is representative of the overall formation K: the values estimated from slug tests are strongly influenced by the presence of a low-K well skin, drilling-induced disturbances, highly anisotropic formations, and the quality of well development (Butler 1998, Hyder and Butler 1995). Non-instantaneous or incomplete slug removal, accidental transducer or slug movement after the test began, and other factors may affect the interpretation of slug test results. Some of these factors were present in some of the GRTS slug tests, but generally when both the rising and falling head tests were analyzed, the results were consistent within each well.

Table 2 Slug Test Results

Well	Date	Mean Hydraulic Conductivity		Logged Lithology of Screened Interval
		(feet/day)	(cm/sec)	
GRTS-MW01A	5/14/2018	1.4	4.8×10^{-04}	Clay to silt
GRTS-MW01B	5/15/2018	0.0036	1.3×10^{-06}	Clay
GRTS-MW02A	5/15/2018	0.0015	5.2×10^{-07}	Silt to clay
GRTS-MW02B	5/16/2018	0.0017	6.0×10^{-07}	Clay to sandy silt
GRTS-MW03A	5/14/2018	1.1	3.8×10^{-04}	Clay
GRTS-MW03B	5/16/2018	0.0022	7.7×10^{-07}	Clay to silt
GRTS-MW04A	5/14/2018	0.085	3.0×10^{-05}	Clay to sandy silt
GRTS-MW04B	5/15/2018	0.0024	8.5×10^{-07}	Silt to clay
GRTS-MW05A	5/15/2018	0.057	2.0×10^{-05}	Clay
GRTS-MW05B	5/16/2018	0.014	4.8×10^{-06}	Clay
ES-13	5/16/2018	0.001	3.5×10^{-07}	Clay
MCF-06B	5/15/2018	0.0029	1.0×10^{-06}	Clay

Notes:
cm/sec - centimeters per second

Table 3 Water Levels

Well	Date	Total Depth (feet btoc)	Water Level (feet btoc)
GRTS-MW01A	5/14/2018	80.30	47.18
GRTS-MW01B	5/15/2018	110.31	57.33
GRTS-MW02A	5/15/2018	80.01	56.36
GRTS-MW02B	5/16/2018	109.91	64.23
GRTS-MW03A	5/14/2018	75.45	53.21
GRTS-MW03B	5/16/2018	111.10	60.82
GRTS-MW04A	5/14/2018	85.64	50.40
GRTS-MW04B	5/15/2018	110.41	57.17
GRTS-MW05A	5/15/2018	70.00	52.86
GRTS-MW05B	5/16/2018	85.45	55.45
ES-13	5/16/2018	107.15	60.77
MCF-06B	5/15/2018	85.15	58.16

Notes:
btoc - below top of casing

SINGLE-BOREHOLE DILUTION TESTS

A single-borehole (or point) dilution test uses the change in concentration with time of a tracer compound emplaced in a well to estimate groundwater flow velocity. The theoretical basis for the single-borehole dilution method has been summarized by Halevy et al. (1967) and Drost et al (1968). Pitrak et al. (2007) elaborated on the use of these analytical techniques and restated the equations in somewhat simpler form. The apparent flow velocity equation from Pitrak et al. (2007) is:

$$\ln C = -\frac{2v_a}{\pi r}t + ln\, C_0$$

where:

C is the tracer concentration at time t
v_a is the apparent flow velocity
r is the borehole radius
t is time
C_0 is the initial tracer concentration

The apparent flow velocity estimated from the above equation must be adjusted by a distortion factor α to obtain actual flow velocity (Halevy et al., 1967). The distortion factor accounts for perturbations in the flow field caused by the contrast between the hydraulic properties of the well and the surrounding undisturbed aquifer. The following equation (Halevy et al., 1967) is used to estimate α:

$$\alpha = \frac{4}{1 + \left(\frac{r_1}{r_2}\right)^2 + \left(\frac{k_2}{k_1}\right)\left[1 - \left(\frac{r_1}{r_2}\right)^2\right]}$$

where

r_1 is the inner well casing radius
r_2 is the combined radius of the well casing and filter pack
k_1 is the permeability of the combined well casing and filter pack
k_2 is the permeability of the undisturbed formation

For this analysis, the filter pack and well casing were assumed to have similar permeability, since both are at least one order of magnitude greater than the formation and neither is known exactly. Furthermore, the dynamic viscosity, fluid density, and gravitational acceleration components of the hydraulic conductivity cancel in this equation, so the permeability ratio is identical to the hydraulic conductivity ratio (i.e., $K_2/K_1 = k_2/k_1$). The filter pack of each well has an estimated hydraulic conductivity of 100 ft/day; the hydraulic conductivity of the undisturbed formation was estimated from slug tests performed at each of the wells, as described above. Using the appropriate radii and the estimated hydraulic conductivity ratios, α was estimated for each well.

Groundwater in the UMCf in the study area has a specific conductance of approximately 10,000 to 60,000 microsiemens per centimeter (µS/cm), depending on the depth interval screened. It is therefore possible to use distilled water, which has a specific conductance of approximately 0 µS/cm, as a tracer for the purpose of the test. Assuming that specific conductance is directly proportional to the fraction of groundwater in the groundwater-distilled water mixture in a well, the tracer concentration can be calculated from:

$$F_{dw} = \frac{SC_0 - SC_t}{SC_0}$$

where
F_{dw} is the fraction of distilled water in the groundwater-distilled water mixture
SC_0 is the specific conductance of the groundwater
SC_t is the specific conductance of the mixture at time t

Field Procedure

The single-borehole dilution tests were performed between June 18-29, 2018. Two tests were performed at GRTS-MW03A to confirm the rapid recovery observed at the well; the second test was performed in a slightly different portion of the screened interval but ultimately resulted in reasonably comparable estimated groundwater velocities. Specific conductance was monitored during the test using a water quality and pressure transducer (In-Situ Aqua TROLL 200) placed in the well at the center of the screened interval. The sensor calibration was checked immediately prior to performing the test in accordance with manufacturer's specifications, using a standard calibration solution.

The tracer was delivered to the well by simultaneously pumping water from the well and replacing it with distilled water. The pump was placed near the bottom of the well, and the discharge hose was connected to a container at the top of the well. The distilled water was emplaced in the well at a rate designed to equal the pump's discharge rate to minimize hydraulic head changes in the well. The water exchange continued until approximately one casing volume was removed and replaced with distilled water.

The transducer was monitored during water emplacement to ensure that the specific conductance decreased quickly and stabilized at a significantly lower value. The transducer was then allowed to remain in the well to measure recovery of specific conductance. The data were downloaded periodically until the specific conductance values stabilized at or near the original pre-test values or until significant recovery had occurred (in cases of recovery times exceeding 24 hours).

Data Interpretation

The apparent flow velocity equation can be solved graphically by plotting the natural logarithm of the tracer concentration against time, and then fitting a straight line to the data. Plots of the natural logarithm of F_{dw} vs. time for each of the wells tested are shown in ***Figure 2***.

Review of the plots of the natural logarithm of F_{dw} vs. time reveals the following:

- The data for GRTS-MW03B are sporadic and noisier than the data for GRTS-MW03A.
- The early data for GRTS-MW03A (test 1) have an anomalously shallow or positive slope. This is not observed in the data for GRTS-MW03A (test 2) or for GRTS-MW03B and is believed to be due to mixing within the borehole in the initial phases of the test.
- The middle data are relatively linear.
- The late data, which represent relatively large dilutions, are characterized by slightly shallower slopes than the middle data, and are typically concave-upward.

The missing and noisy data at GRTS-MW03B are the result of a faulty transducer which recorded spurious values when disconnected from the computer. After this issue was identified, field staff were able to obtain useable data by returning to the well and reconnecting the transducer to the computer at regular intervals, producing the small groups of data shown on the plot. The periodic downloads allowed collection of a reasonable amount of data on this very slow-recovering well, rendering repetition of the test unnecessary.

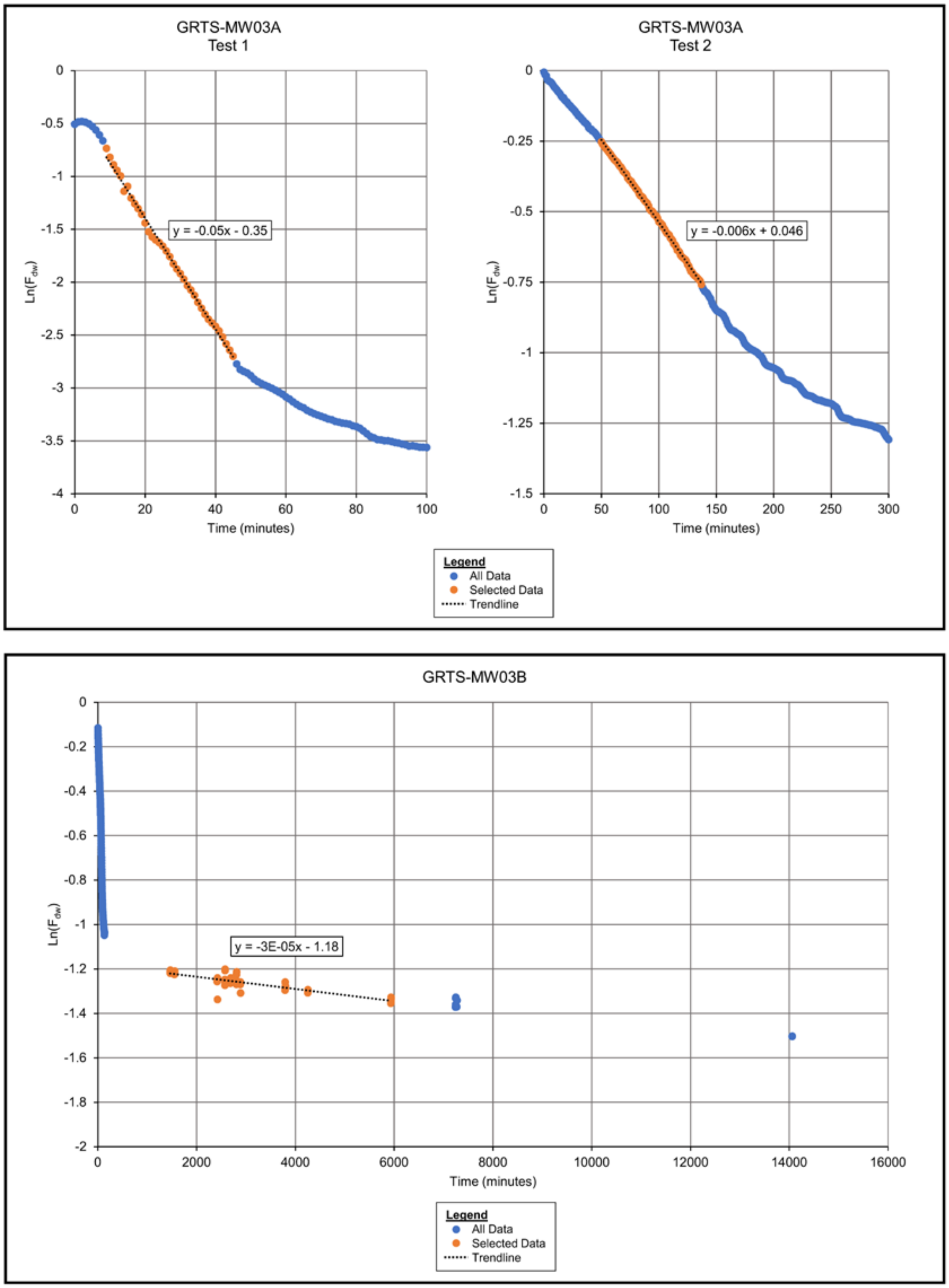

Figure 2 **Plots of the natural logarithm of F_{dw} vs. time**

Where anomalous early-time data are present, they are interpreted to be a result of vertical mixing within the well casing, caused by rapid removal of the pump and tubing immediately after the test was initiated. The relatively linear middle portion of the curve (present in all three tests) is considered to be representative of the period when most of the tracer dilution occurred, and was therefore used for analysis. The least-squares straight lines and the equations of the lines are shown above.

Distortion factors were calculated as described above using the radii of the wells and the hydraulic conductivity of the formation estimated from the slug testing described in the previous section. Calculated distortion factors, apparent velocities estimated from the slopes of the least-squares lines, and calculated flow velocities are summarized in ***Table 4***.

Table 4 Single-Borehole Dilution Test Results

Well	Initial Time (minutes)	Initial F_{dw}	Final Time (minutes)	Final F_{dw}	Slope of Least Squares Line	Apparent Velocity (feet/day)	Distortion Factor α	Flow Velocity (feet/day)
GRTS-MW03A	9	0.48	45	0.067	-0.05	19	3.18	6
	50	0.78	137	0.47	-0.01	2	3.18	0.7
					Average Velocity	10.5		3.4
GRTS-MW03B	1464	0.30	5937	0.26	-0.003	0.011	3.20	0.0035

Notes:
F_{dw}: Fraction of distilled water

Table 4 shows that the flow velocity in the UMCf is much greater in the shallow portion of the aquifer than in the deeper portion.

NUCLEAR MAGNETIC RESONANCE LOGGING

NMR logging was performed in the deeper well of the five paired well configurations (namely GRTS-MW01B, GRTS-MW02B, GRTS-MW03B, GRTS-MW04B, and GRTS-MW05B) to further delineate any localized preferential flow pathways within the treatability study area. Although the *Galleria Road Bioremediation Treatability Study Work Plan* (Tetra Tech, 2017) optionally proposed NMR logging for existing wells, scheduling constraints associated with larger NMR site-wide efforts limited the amount of logging that could be performed. As a result, only the five, deeper new wells were logged as part of Phase I activities. The reduced number of NMR surveys will not negatively affect this treatability study as the NMR results received for this effort provided the information needed for final treatability study design.

NMR logging was used successfully at the SWF Area Bioremediation Treatability Study to identify higher-transmissivity zones within each well. This technology can be used in open or PVC-cased wells to provide high-resolution downhole estimates of hydraulic conductivity, total water content, total and mobile porosity, and relative pore-size distributions below the water table (Walsh et al, 2013). Above the water table, NMR provides volumetric water content measurements. The specific tool used depended on the diameter of the well, because larger diameter wells require a larger tool that has a larger radius of investigation. All tools provided a measurement approximately every 1.5 to 2 feet of depth. The high-resolution estimates of hydraulic conductivity were compared to the lithologic logs and aquifer testing results for each well to assess the possibility of preferential flow. The final NMR logging profiles are provided in Attachment A.2.

Because the translation of NMR data to hydraulic conductivity requires the use of an empirical relationship, the correct model for the degree of consolidation of the formation must be selected in order to yield accurate estimates of hydraulic conductivity. The boreholes examined using NMR transitioned from unconsolidated to semi-consolidated UMCf, so the unconsolidated model was used for the upper portion of each borehole, and the semi-consolidated model was used for the lower portion. The transition to the semi-consolidated model was identified based on the observed level of cementation (moderately to strongly cemented) and consistency (stiff, very stiff, or hard). If neither of these data types was available, UMCf lithology was used to determine the dividing line, with clays indicating a more consolidated region. The dividing line between unconsolidated and semi-consolidated materials was located at the shallowest depth in which the available data indicated consolidation.

NMR estimates of K generally agreed with estimates derived using slug testing within an order of magnitude, particularly higher in the borehole. However, the drilling-related disturbance zone surrounding the borehole appears to have been larger in the deepest portion of each hole. For the four-inch well (GRTS-MW03B), the larger NMR tool clearly reached beyond the damage zone around the borehole. However, in the two-inch wells, the smaller NMR tool did not consistently penetrate the formation past the damage zone around the borehole. This is observable in the logs as sporadic large increases in the hydraulic conductivity, particularly in the sand-packed interval where the damage zone was not grouted. These irregularities will not affect the treatability study because aquifer properties were estimated using several aquifer testing methods, with the expectation that site-specific conditions might render one method less reliable.

The water content log was particularly useful as it indicated that the water content of the UMCf in the Galleria Road bioremediation treatability study area was not as high as observed at the SWF Area Bioremediation Treatability Study. This data correlated with field observations that the Galleria Road area had significantly more cementation than previously encountered at the SWF Area Treatability Study. Furthermore, the mobile porosity is very low, often below 1%. This corresponds well with the observed groundwater flow velocities, which in spite of low K's are faster than anticipated because of the low effective porosity.

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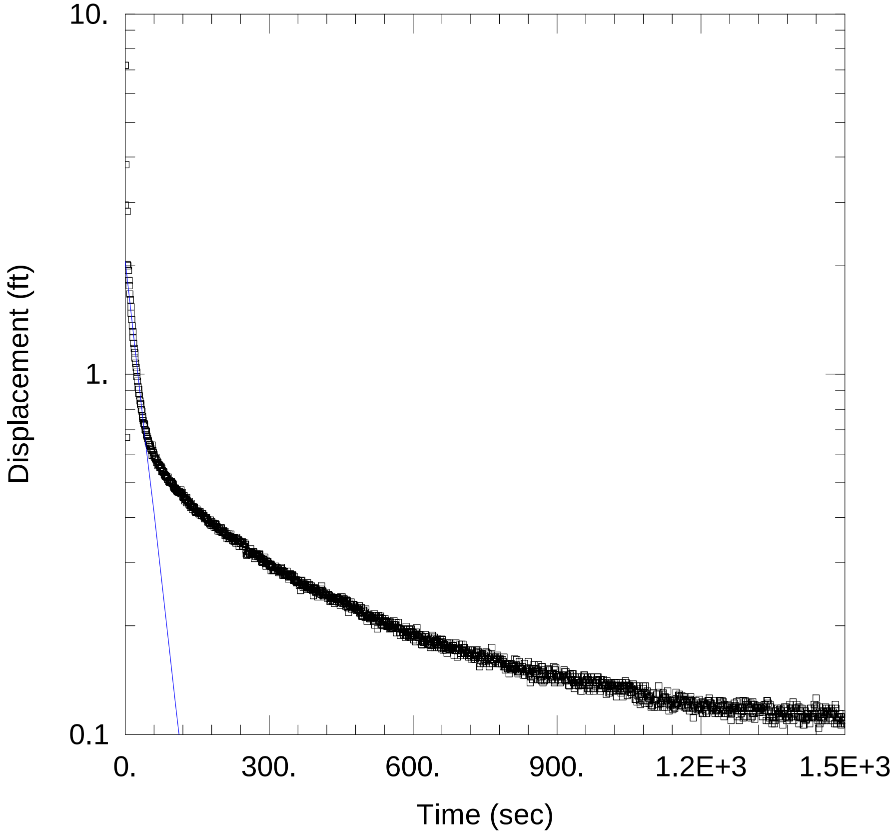
Attachment A.1

AQTESOLV Interpretation Plots



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW01A_IN1.aqt
Date: 06/07/18 Time: 12:10:08

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW01A
Test Date: 5/14/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

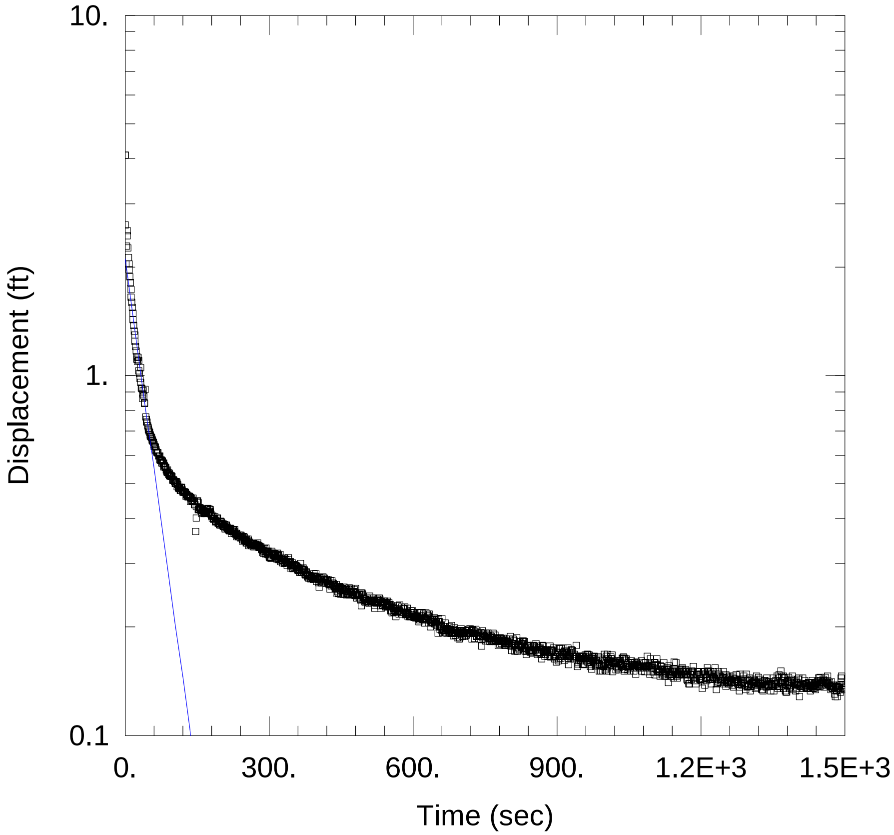
K = 1.483 ft/day
y0 = 2.053 ft

AQUIFER DATA

Saturated Thickness: 22.5 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW01A_IN1)

Initial Displacement: 7.194 ft
Total Well Penetration Depth: 33.12 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 33.12 ft
Screen Length: 20. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW01A_OUT1.aqt
Date: 06/07/18 Time: 12:10:44

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW01A
Test Date: 5/14/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

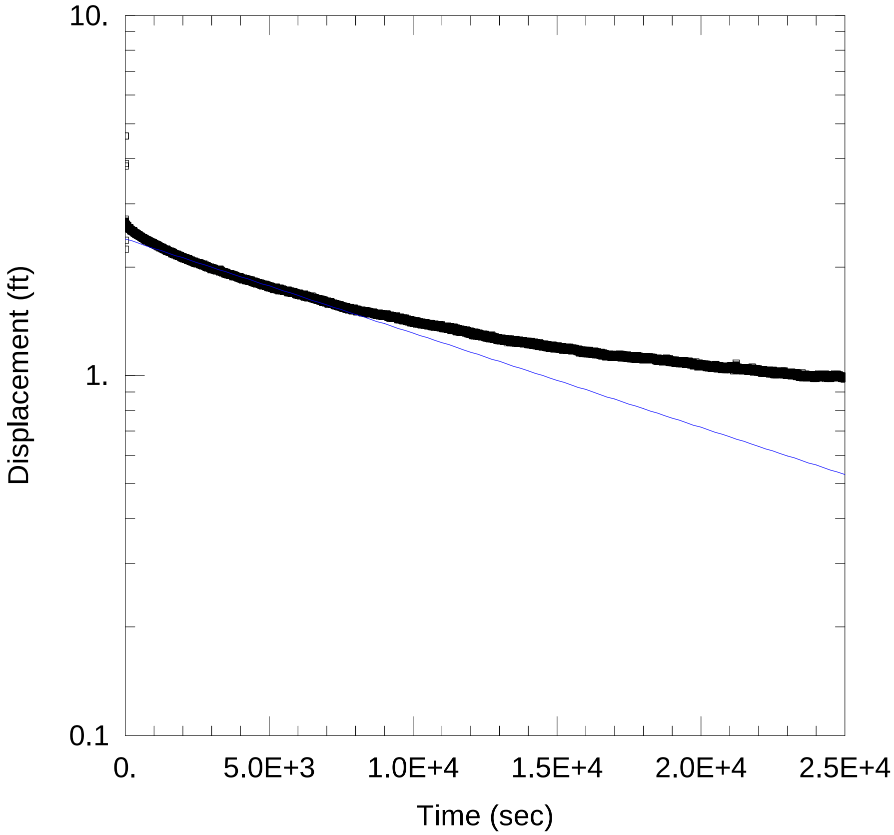
K = 1.233 ft/day
y0 = 2.104 ft

AQUIFER DATA

Saturated Thickness: 22.5 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW01A_OUT1)

Initial Displacement: 4.092 ft
Total Well Penetration Depth: 33.12 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 33.12 ft
Screen Length: 20. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW01B_IN1 - BM Revised.aqt
Date: 06/07/18 Time: 12:12:34

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW01B
Test Date: 5/15/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

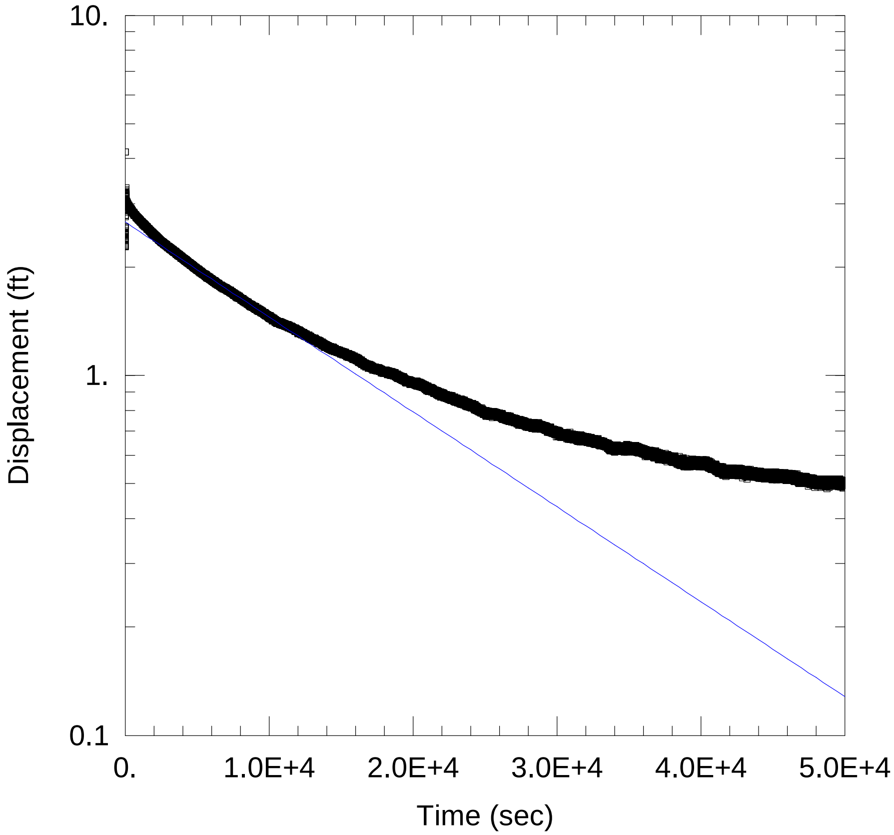
K = 0.003599 ft/day
y0 = 2.394 ft

AQUIFER DATA

Saturated Thickness: 22. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW01B_IN1)

Initial Displacement: 4.617 ft
Total Well Penetration Depth: 52.98 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 52.98 ft
Screen Length: 20. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW01B_OUT1 - BM Revised.aqt
Date: 06/07/18 Time: 12:12:59

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW01B
Test Date: 5/15/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

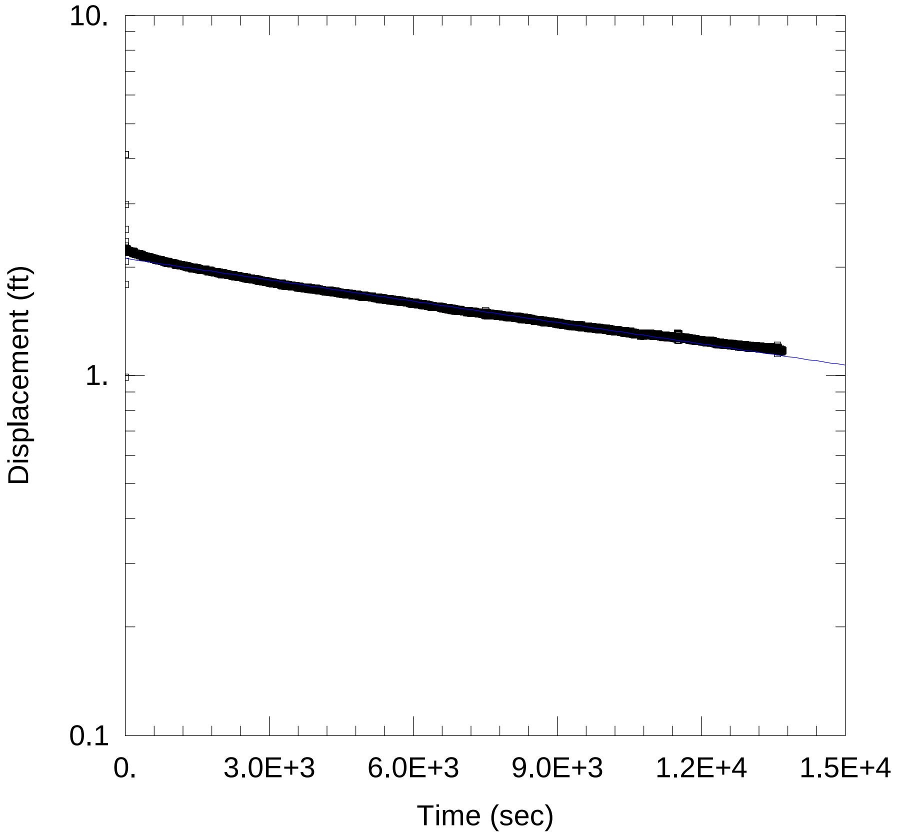
K = 0.003623 ft/day
y0 = 2.666 ft

AQUIFER DATA

Saturated Thickness: 22. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW01B_OUT1)

Initial Displacement: 4.169 ft
Total Well Penetration Depth: 52.98 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 52.98 ft
Screen Length: 20. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW02A_IN1 - BM Revised.aqt
Date: 06/07/18 Time: 12:13:20

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW02A
Test Date: 5/15/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.00237 ft/day
y0 = 2.111 ft

AQUIFER DATA

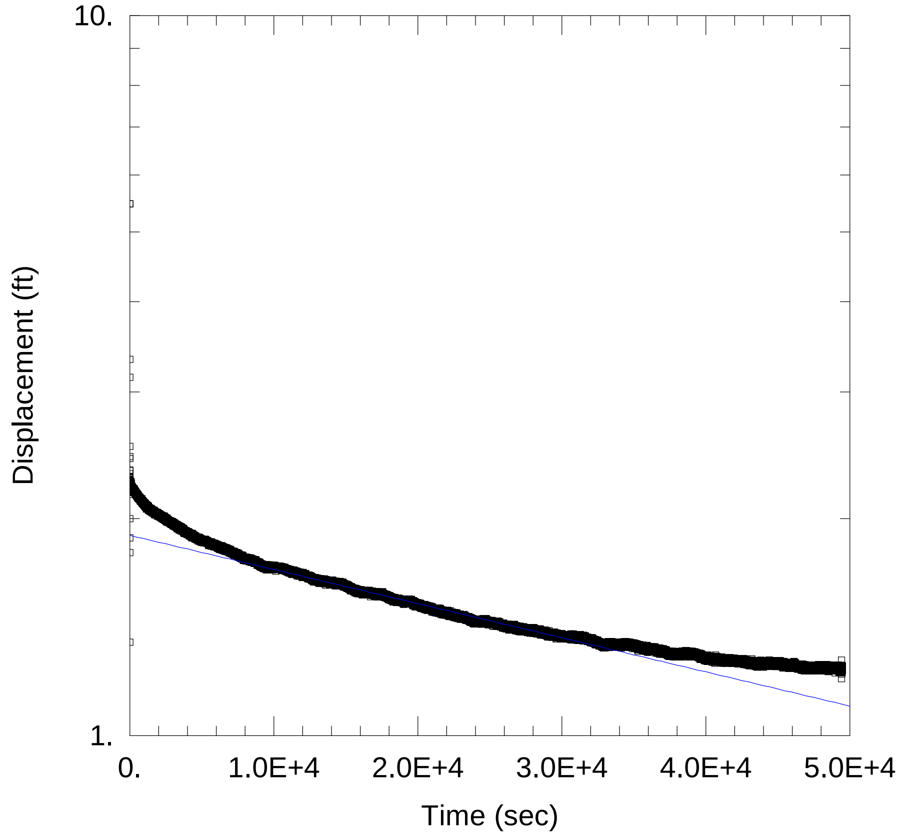
Saturated Thickness: 22.5 ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW02A_IN1)

Initial Displacement: 4.111 ft
Total Well Penetration Depth: 23.65 ft
Casing Radius: 0.08333 ft

Static Water Column Height: 23.65 ft
Screen Length: 20. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW02A_OUT1 - BM Revised.aqt
Date: 06/07/18 Time: 12:14:09

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW02A
Test Date: 5/15/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

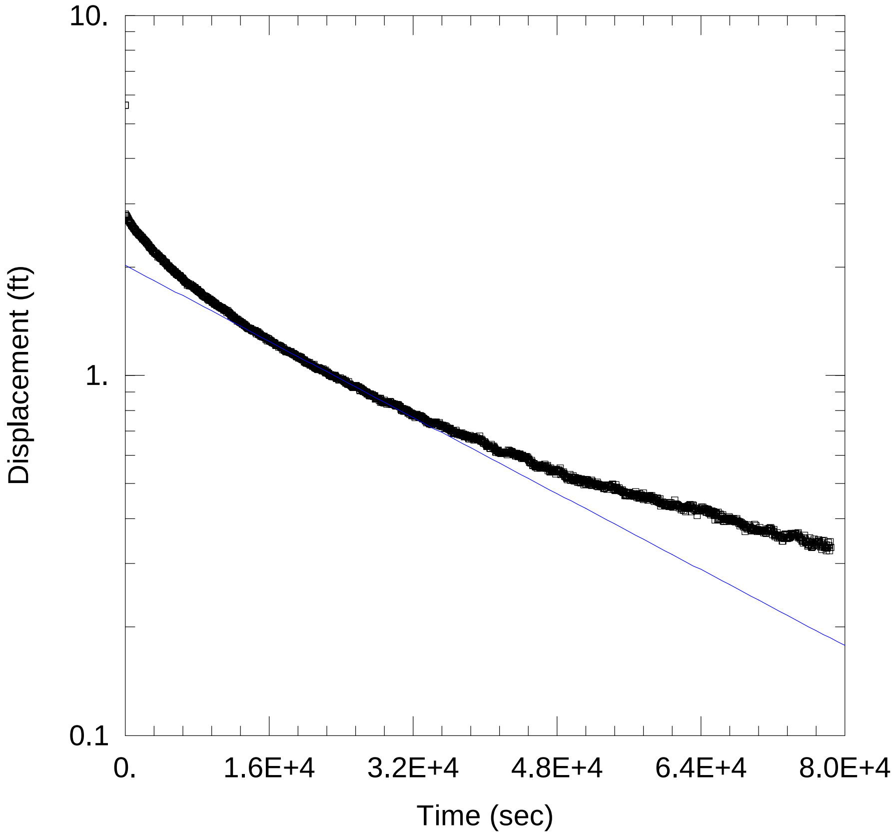
K = 0.0005694 ft/day
y0 = 1.896 ft

AQUIFER DATA

Saturated Thickness: 22.5 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW02A_OUT1)

Initial Displacement: 5.469 ft
Total Well Penetration Depth: 23.65 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 23.65 ft
Screen Length: 20. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW02B_IN1 - BM Revised.aqt
Date: 06/07/18 Time: 12:14:23

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW02B
Test Date: 5/16/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

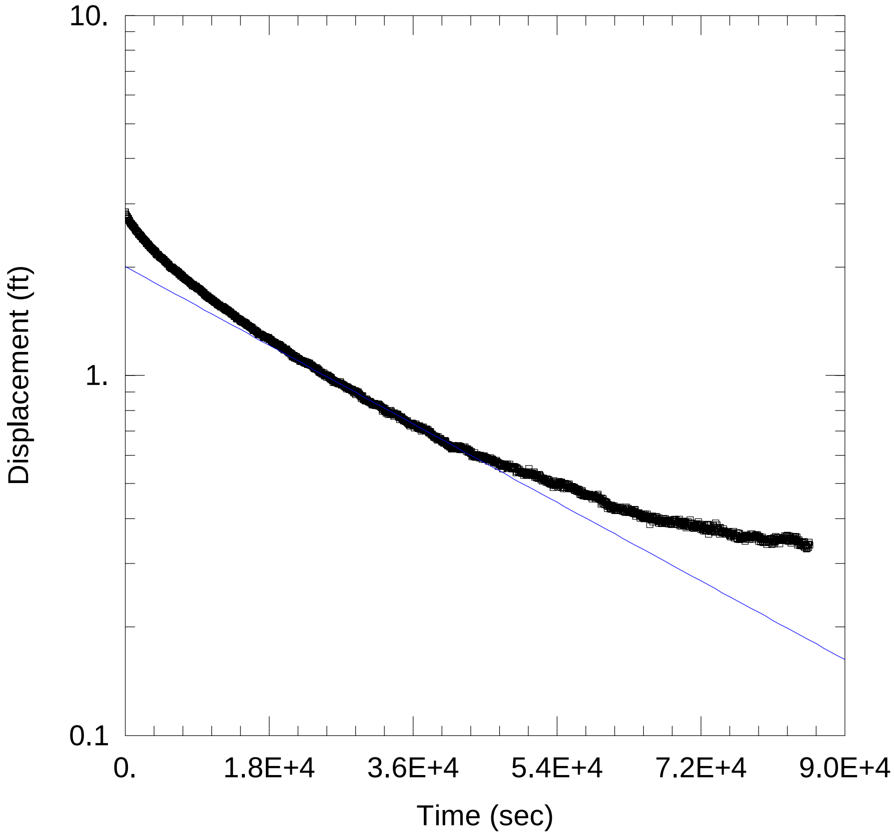
K = 0.001774 ft/day
y0 = 2.023 ft

AQUIFER DATA

Saturated Thickness: 22.8 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW02B_IN1)

Initial Displacement: 5.633 ft
Total Well Penetration Depth: 45.68 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 45.68 ft
Screen Length: 20. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW02B_OUT1 - BM Revised.aqt
Date: 06/07/18 Time: 12:14:33

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW02B
Test Date: 5/16/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

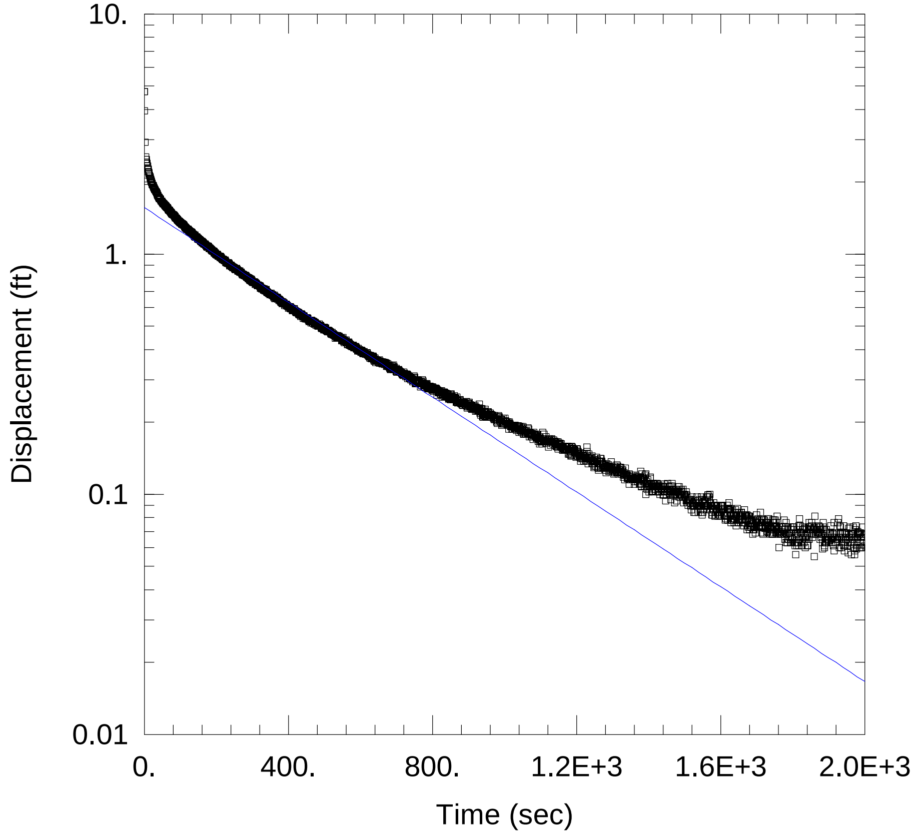
K = 0.001629 ft/day
y0 = 2.005 ft

AQUIFER DATA

Saturated Thickness: 22.8 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW02B_OUT11)

Initial Displacement: 2.844 ft
Total Well Penetration Depth: 45.68 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 45.68 ft
Screen Length: 20. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW03A_IN1_ES.aqt
Date: 06/07/18 Time: 12:15:02

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW03A
Test Date: 5/14/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

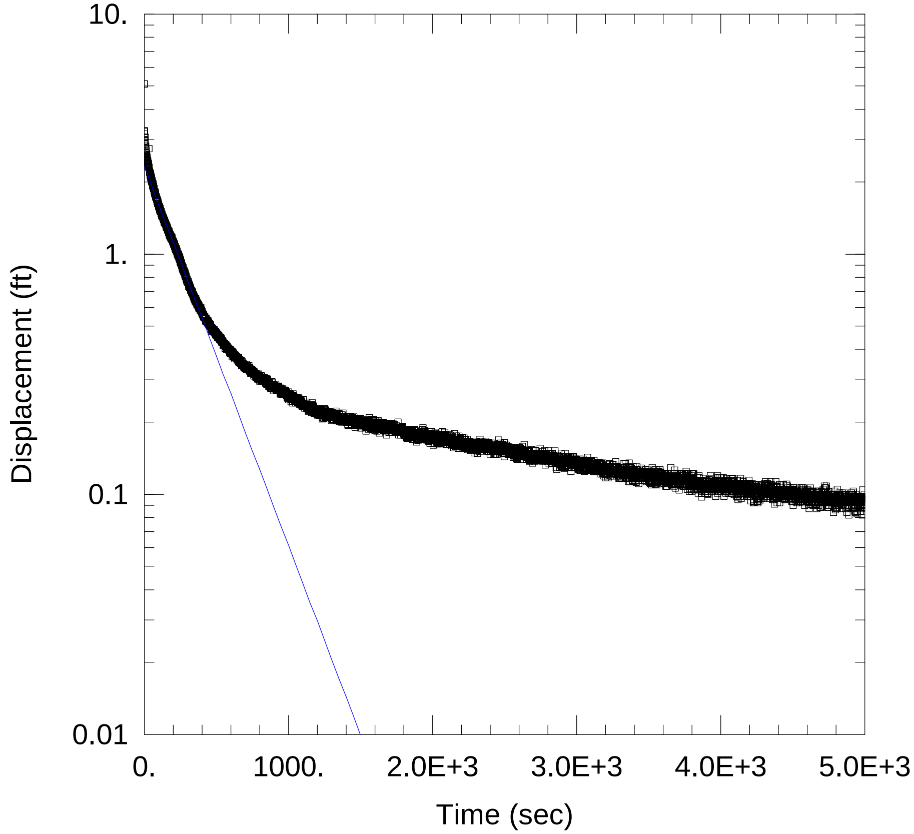
K = 0.8323 ft/day
y0 = 1.56 ft

AQUIFER DATA

Saturated Thickness: 12. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW03A_IN1)

Initial Displacement: 4.754 ft
Total Well Penetration Depth: 22.24 ft
Casing Radius: 0.1667 ft
Static Water Column Height: 22.24 ft
Screen Length: 10. ft
Well Radius: 0.3333 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW03A_OUT1.aqt
Date: 06/07/18 Time: 12:15:18

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW03A
Test Date: 5/14/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

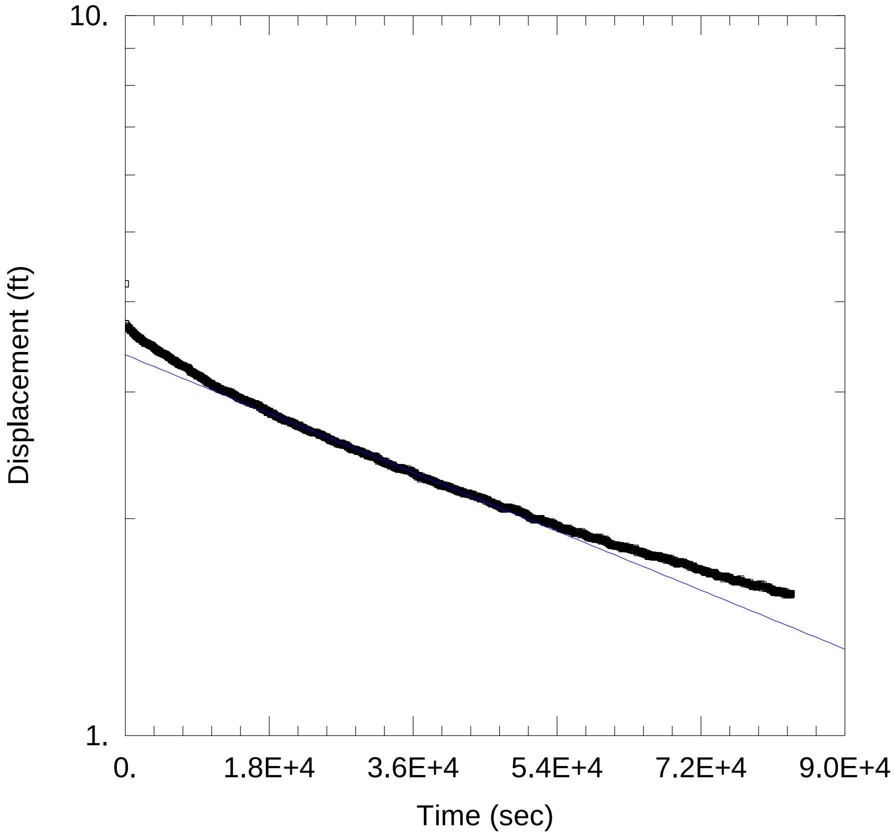
K = 1.331 ft/day
y0 = 2.321 ft

AQUIFER DATA

Saturated Thickness: 12. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW03A_OUT1)

Initial Displacement: 5.116 ft
Total Well Penetration Depth: 22.24 ft
Casing Radius: 0.1667 ft
Static Water Column Height: 22.24 ft
Screen Length: 10. ft
Well Radius: 0.3333 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW03B_IN1 - BM Revised.aqt
Date: 06/07/18 Time: 12:16:36

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW03B
Test Date: 5/16/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

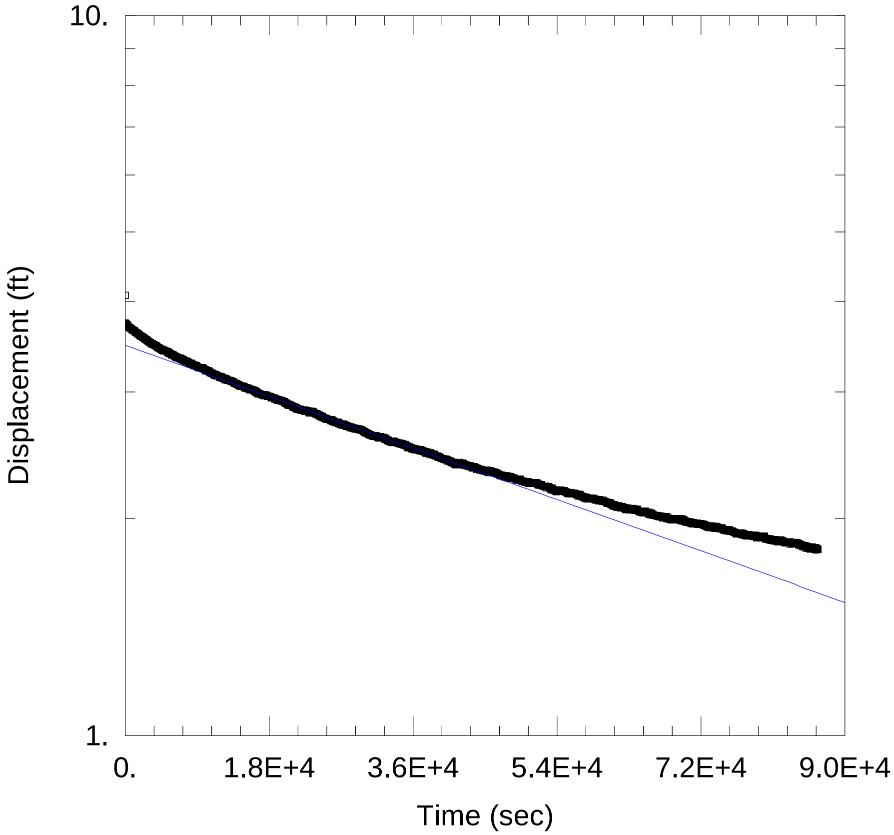
K = 0.002331 ft/day
y0 = 3.377 ft

AQUIFER DATA

Saturated Thickness: 22.2 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW03B_IN1)

Initial Displacement: 4.241 ft
Total Well Penetration Depth: 50.28 ft
Casing Radius: 0.1667 ft
Static Water Column Height: 50.28 ft
Screen Length: 20. ft
Well Radius: 0.3333 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW03B_OUT1 - BM Revised.aqt
Date: 06/07/18 Time: 12:16:45

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW03B
Test Date: 5/16/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

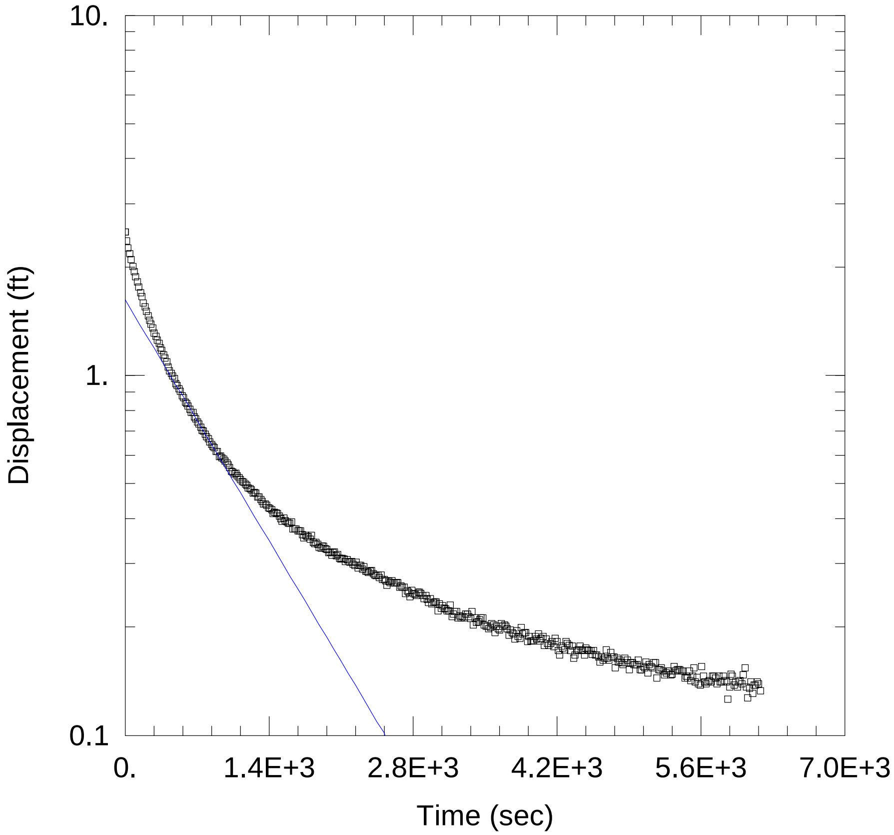
K = 0.002036 ft/day
y0 = 3.481 ft

AQUIFER DATA

Saturated Thickness: 22.2 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW03B_OUT1)

Initial Displacement: 4.087 ft
Total Well Penetration Depth: 50.28 ft
Casing Radius: 0.1667 ft
Static Water Column Height: 50.28 ft
Screen Length: 20. ft
Well Radius: 0.3333 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW04A_IN1.aqt
Date: 06/07/18 Time: 12:17:07

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW04A
Test Date: 5/14/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

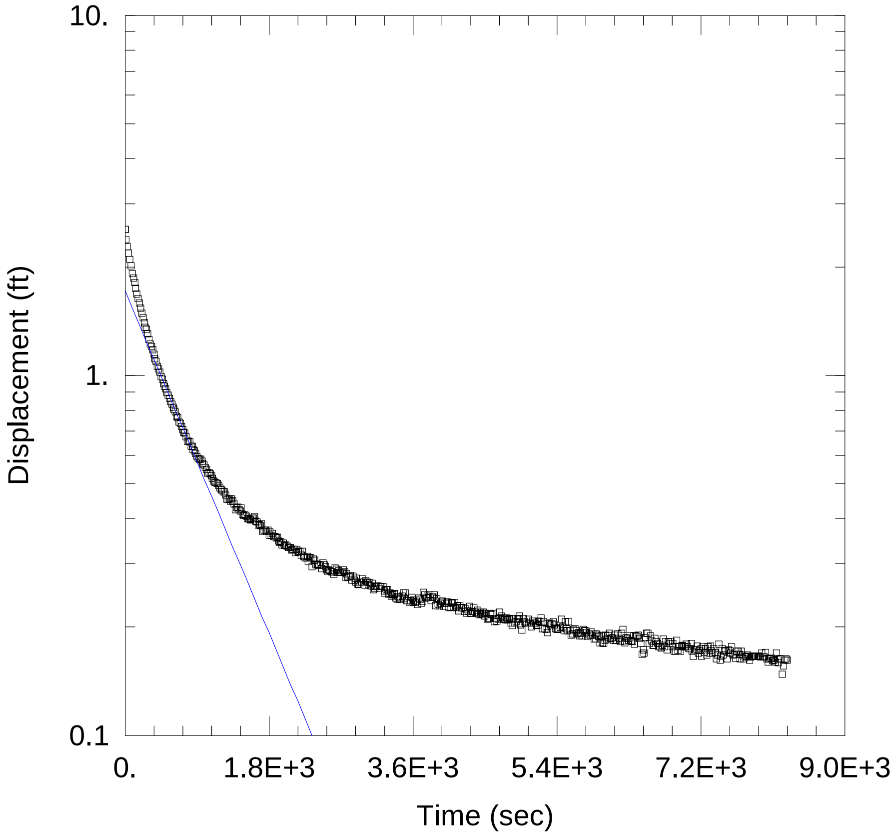
K = 0.08089 ft/day
y0 = 1.622 ft

AQUIFER DATA

Saturated Thickness: 17. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW04A_IN1)

Initial Displacement: 2.504 ft
Total Well Penetration Depth: 35.24 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 35.24 ft
Screen Length: 15. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW04A_OUT1.aqt
Date: 06/07/18 Time: 12:17:27

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW04A
Test Date: 5/14/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

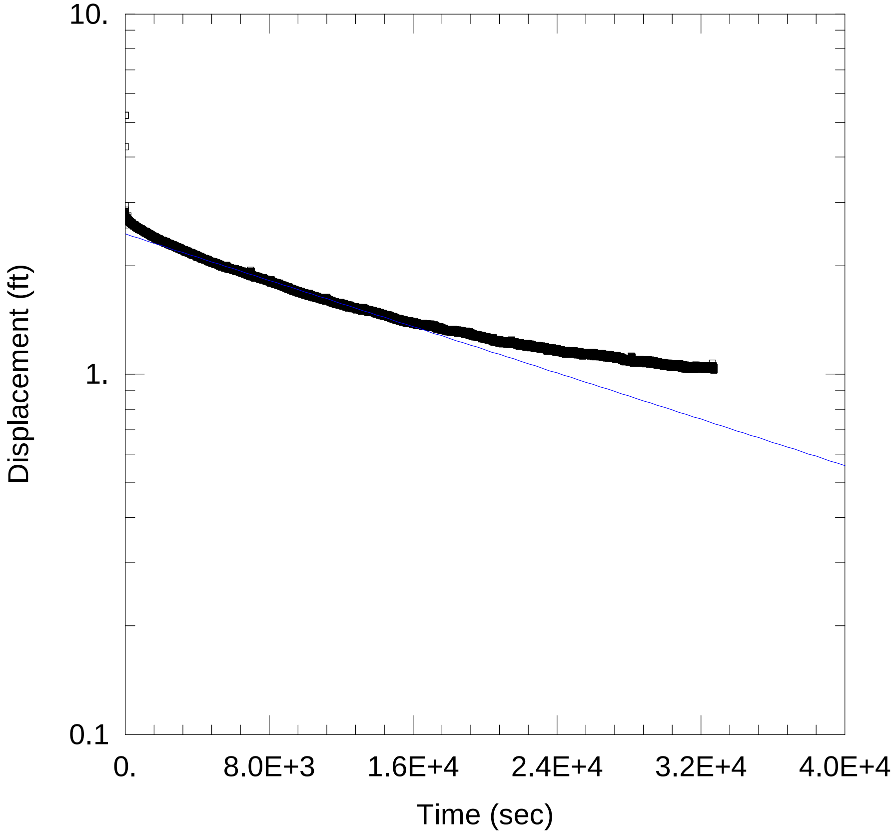
K = 0.08936 ft/day
y0 = 1.718 ft

AQUIFER DATA

Saturated Thickness: 17. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW04A_OUT1)

Initial Displacement: 2.538 ft
Total Well Penetration Depth: 35.24 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 35.24 ft
Screen Length: 15. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW04B_IN1 - BM Revised.aqt
Date: 06/07/18 Time: 12:17:58

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW04B
Test Date: 5/15/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

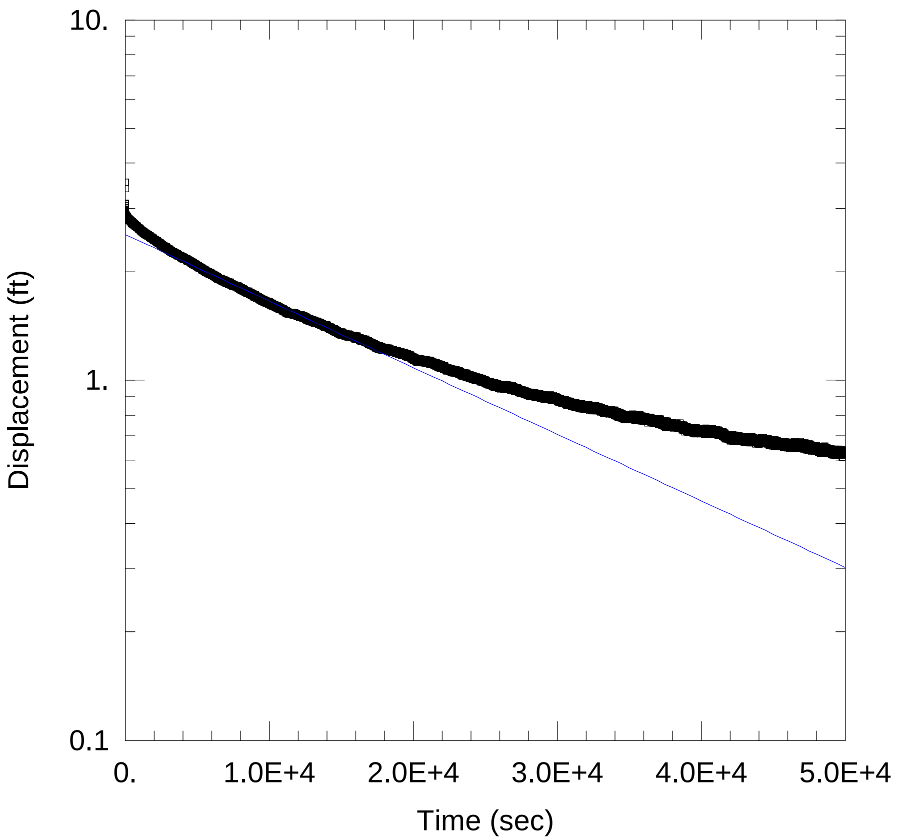
K = 0.002242 ft/day
y0 = 2.448 ft

AQUIFER DATA

Saturated Thickness: 22.5 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW04B_IN1)

Initial Displacement: 5.234 ft
Total Well Penetration Depth: 53.24 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 53.24 ft
Screen Length: 19.7 ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW04B_OUT1 - BM Revised.aqt
Date: 06/07/18 Time: 12:18:23

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW04B
Test Date: 5/15/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

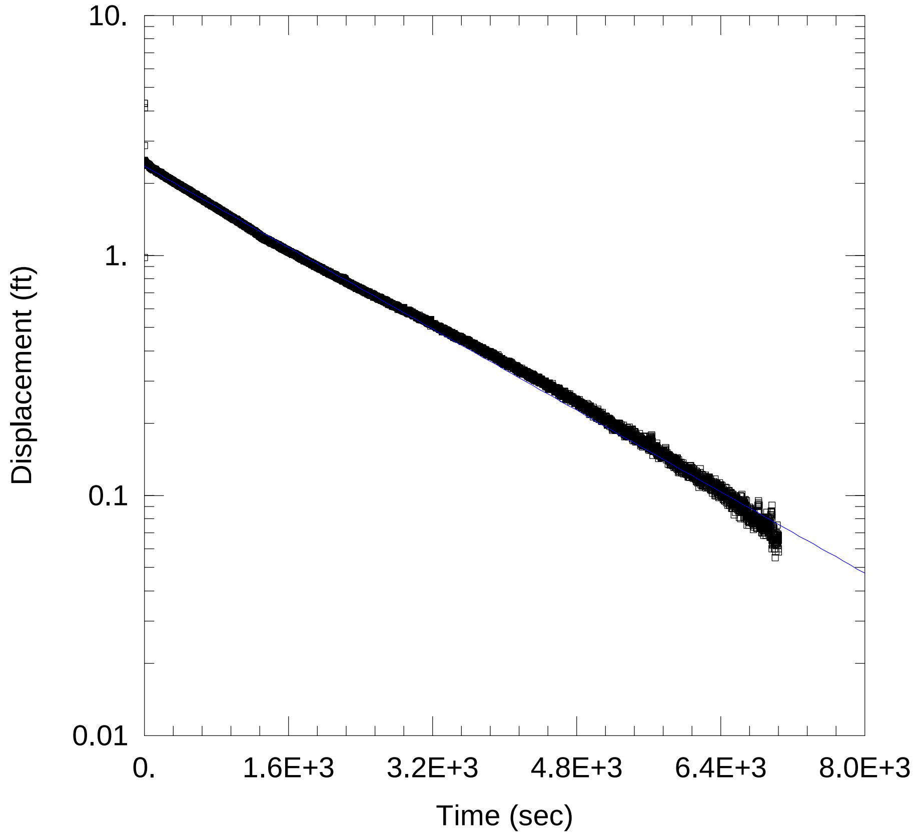
K = 0.002579 ft/day
y0 = 2.537 ft

AQUIFER DATA

Saturated Thickness: 22.5 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW04B_OUT1)

Initial Displacement: 3.538 ft
Total Well Penetration Depth: 53.24 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 53.24 ft
Screen Length: 19.7 ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW05A_IN1.aqt
Date: 06/07/18 Time: 12:18:50

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW05A
Test Date: 5/15/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

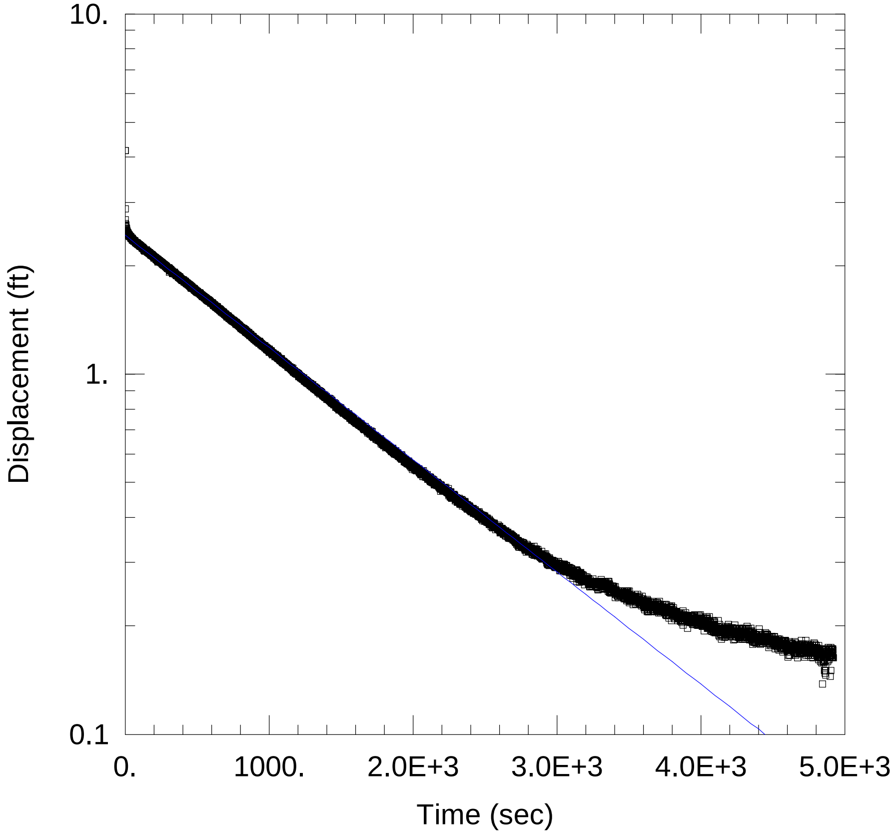
K = 0.04612 ft/day
y0 = 2.359 ft

AQUIFER DATA

Saturated Thickness: 12. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW05A_IN1)

Initial Displacement: 4.294 ft
Total Well Penetration Depth: 17.14 ft
Casing Radius: 0.08333 ft
Static Water Column Height: 17.14 ft
Screen Length: 10. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW05A_OUT1.aqt
Date: 06/07/18 Time: 12:19:02

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW05A
Test Date: 5/15/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.06778 ft/day
y0 = 2.431 ft

AQUIFER DATA

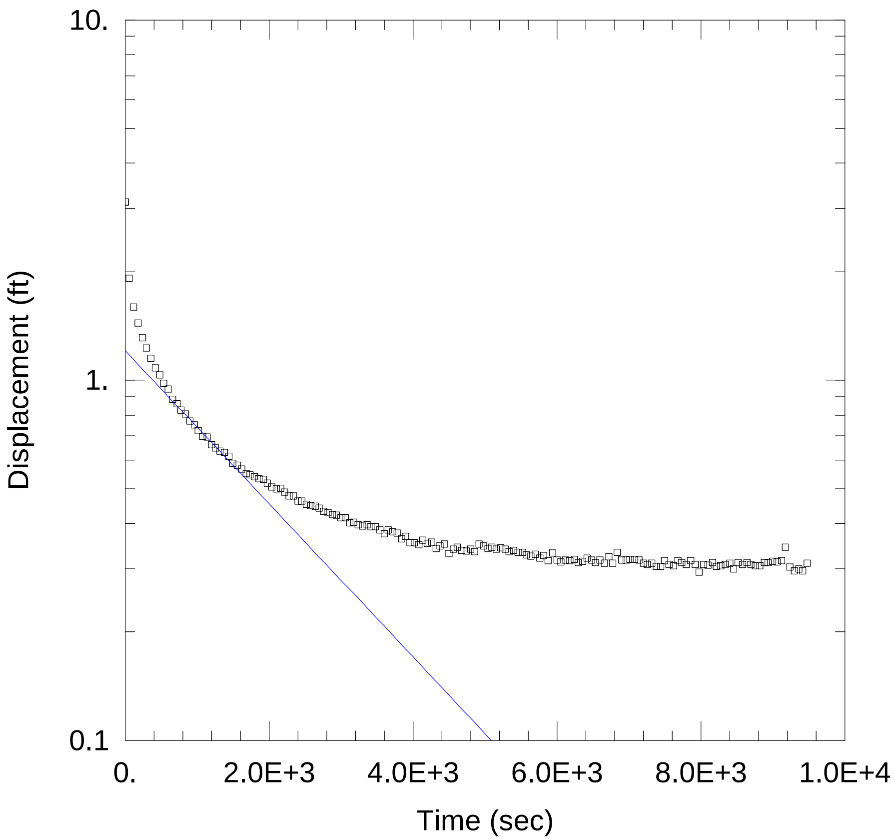
Saturated Thickness: 12. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW05A_OUT1)

Initial Displacement: 4.179 ft
Total Well Penetration Depth: 17.14 ft
Casing Radius: 0.08333 ft

Static Water Column Height: 17.14 ft
Screen Length: 10. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW05B_IN1 - BM Revised_ES.aqt
Date: 06/07/18 Time: 12:19:28

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW05B
Test Date: 5/16/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.05112 ft/day
y0 = 1.208 ft

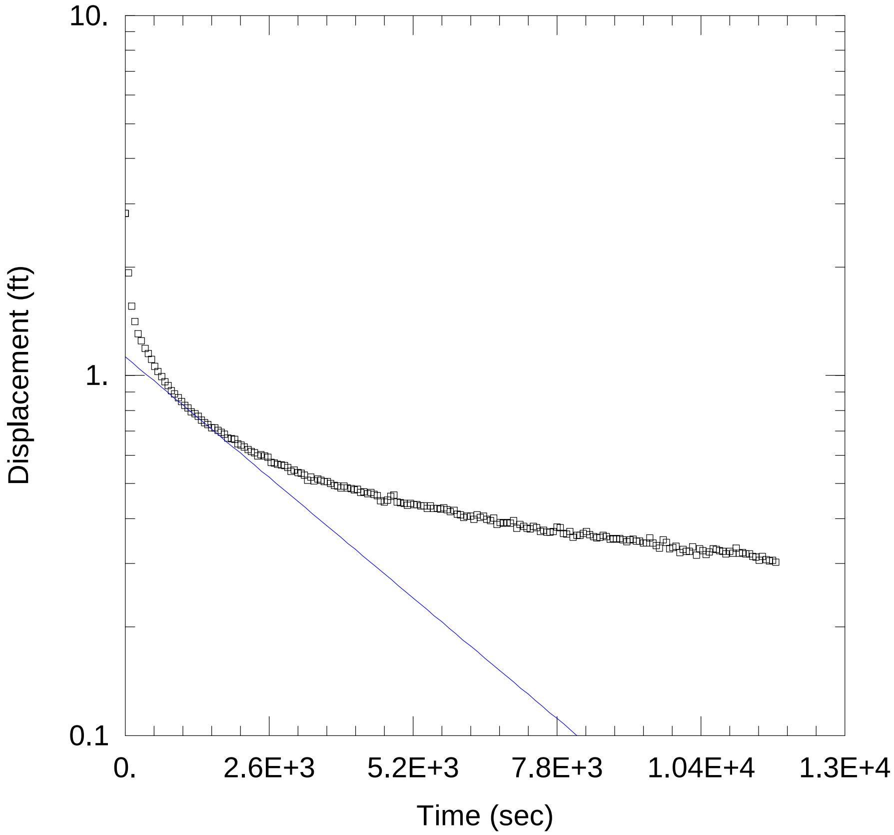
AQUIFER DATA

Saturated Thickness: 12. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW05B_IN1)

Initial Displacement: 3.125 ft
Total Well Penetration Depth: 30. ft
Casing Radius: 0.08333 ft

Static Water Column Height: 30. ft
Screen Length: 10. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: \...\GRTS-MW05B_OUT1 - BM Revised_ES.aqt
Date: 06/07/18 Time: 12:19:41

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: GRTS-MW05B
Test Date: 5/16/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.03099 ft/day
y0 = 1.127 ft

AQUIFER DATA

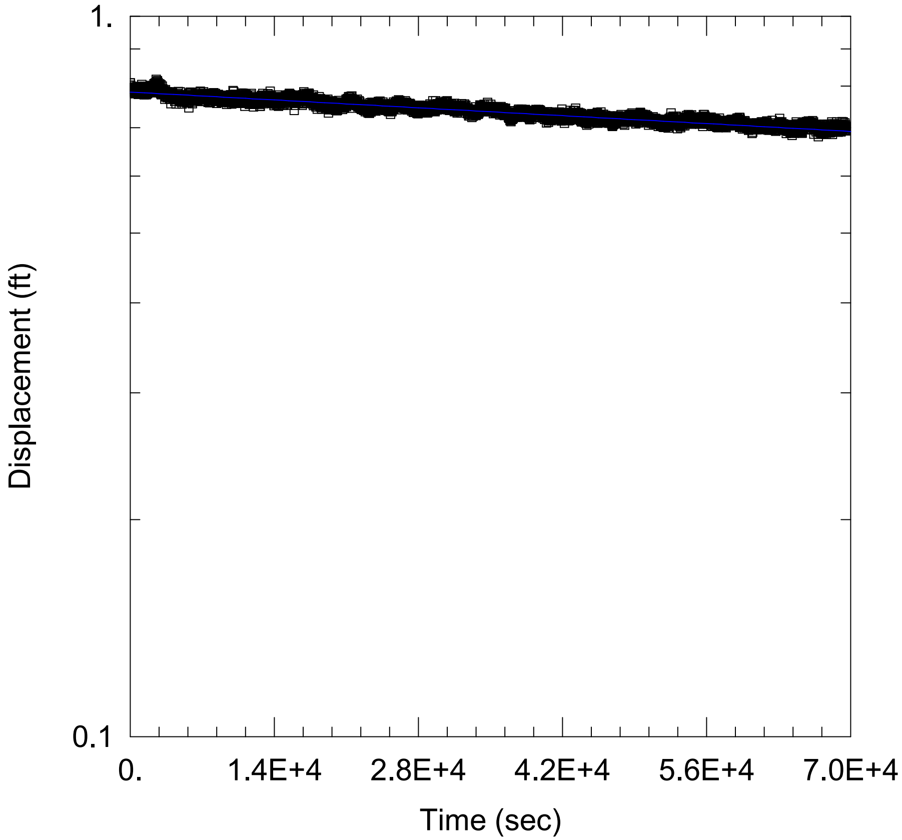
Saturated Thickness: 12. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GRTS-MW05B_OUT1)

Initial Displacement: 2.822 ft
Total Well Penetration Depth: 30. ft
Casing Radius: 0.08333 ft

Static Water Column Height: 30. ft
Screen Length: 10. ft
Well Radius: 0.25 ft



WELL TEST ANALYSIS

Data Set: T:\...\ES-13_IN1 - BM Revised.aqt
Date: 07/05/18 Time: 10:47:27

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: ES-13
Test Date: 5/16/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

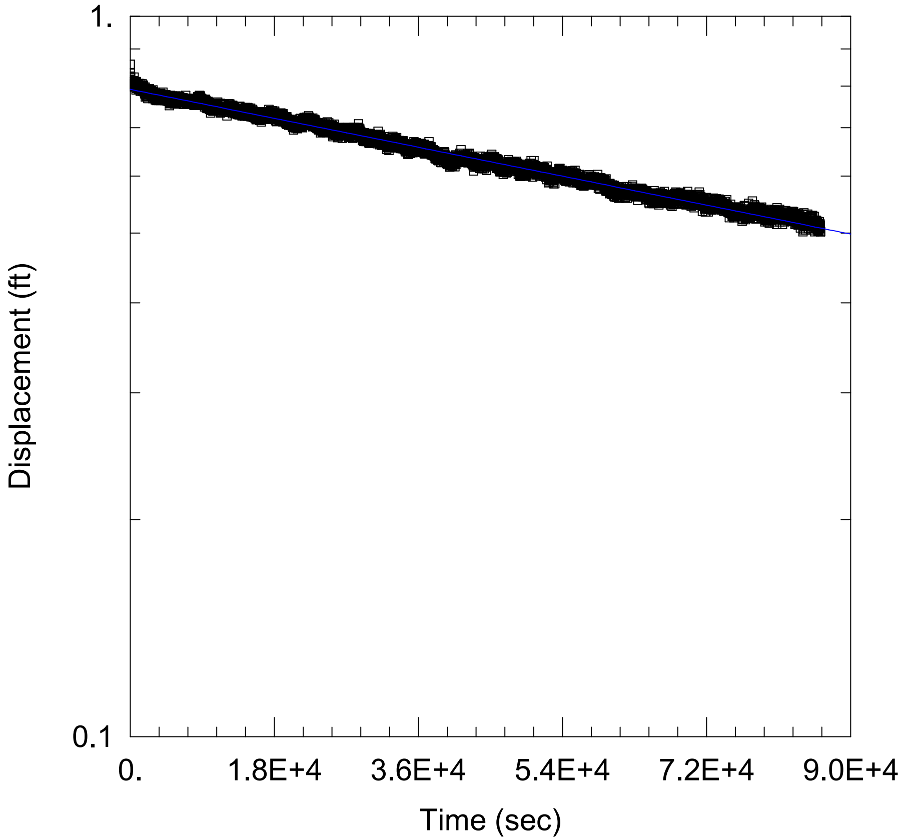
K = 0.000518 ft/day
y0 = 0.7845 ft

AQUIFER DATA

Saturated Thickness: 17. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (ES-13_IN1)

Initial Displacement: 0.808 ft
Total Well Penetration Depth: 46.38 ft
Casing Radius: 0.1667 ft
Static Water Column Height: 46.38 ft
Screen Length: 15. ft
Well Radius: 0.3333 ft



WELL TEST ANALYSIS

Data Set: T:\...\ES-13_OUT1 - BM Revised.aqt
Date: 07/05/18 Time: 10:48:32

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: ES-13
Test Date: 5/16/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.00148 ft/day
y0 = 0.7913 ft

AQUIFER DATA

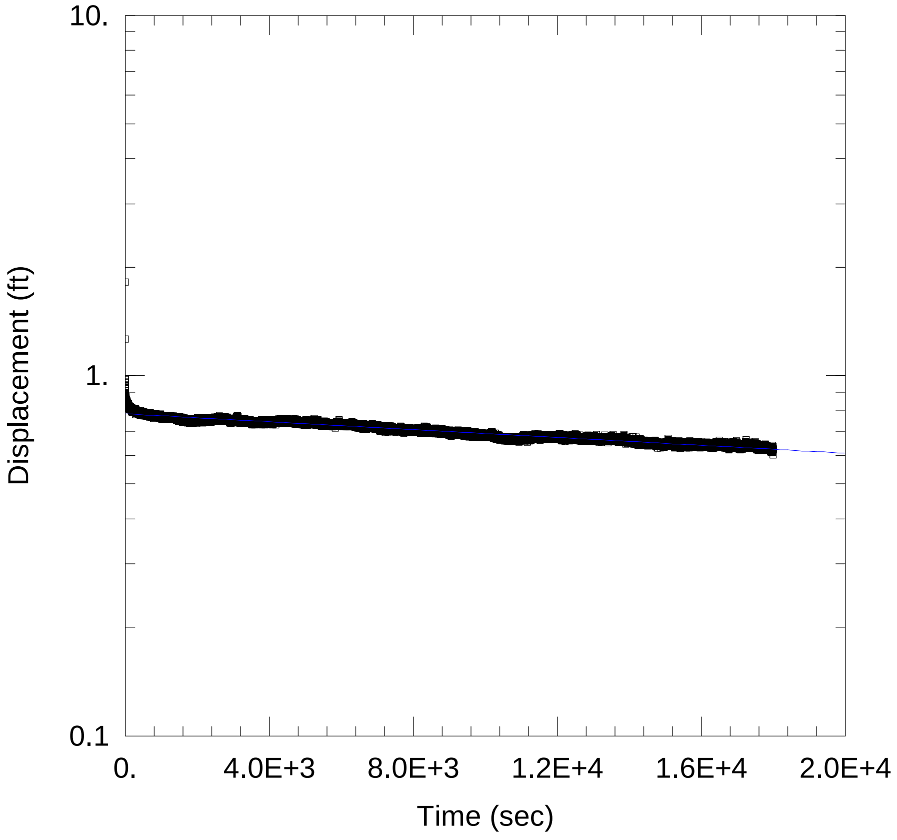
Saturated Thickness: 17. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (ES-13_OUT1)

Initial Displacement: 0.857 ft
Total Well Penetration Depth: 46.38 ft
Casing Radius: 0.1667 ft

Static Water Column Height: 46.38 ft
Screen Length: 15. ft
Well Radius: 0.3333 ft



WELL TEST ANALYSIS

Data Set: \...\MCF-06B_OUT1 - BM Revised.aqt
Date: 06/20/18 Time: 15:19:20

PROJECT INFORMATION

Company: Tetra Tech
Client: NERT
Project: 117-7502018-M17
Location: Henderson, NV
Test Well: MCF-06B
Test Date: 5/15/2018

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.002847 ft/day
y0 = 0.783 ft

AQUIFER DATA

Saturated Thickness: 40. ft

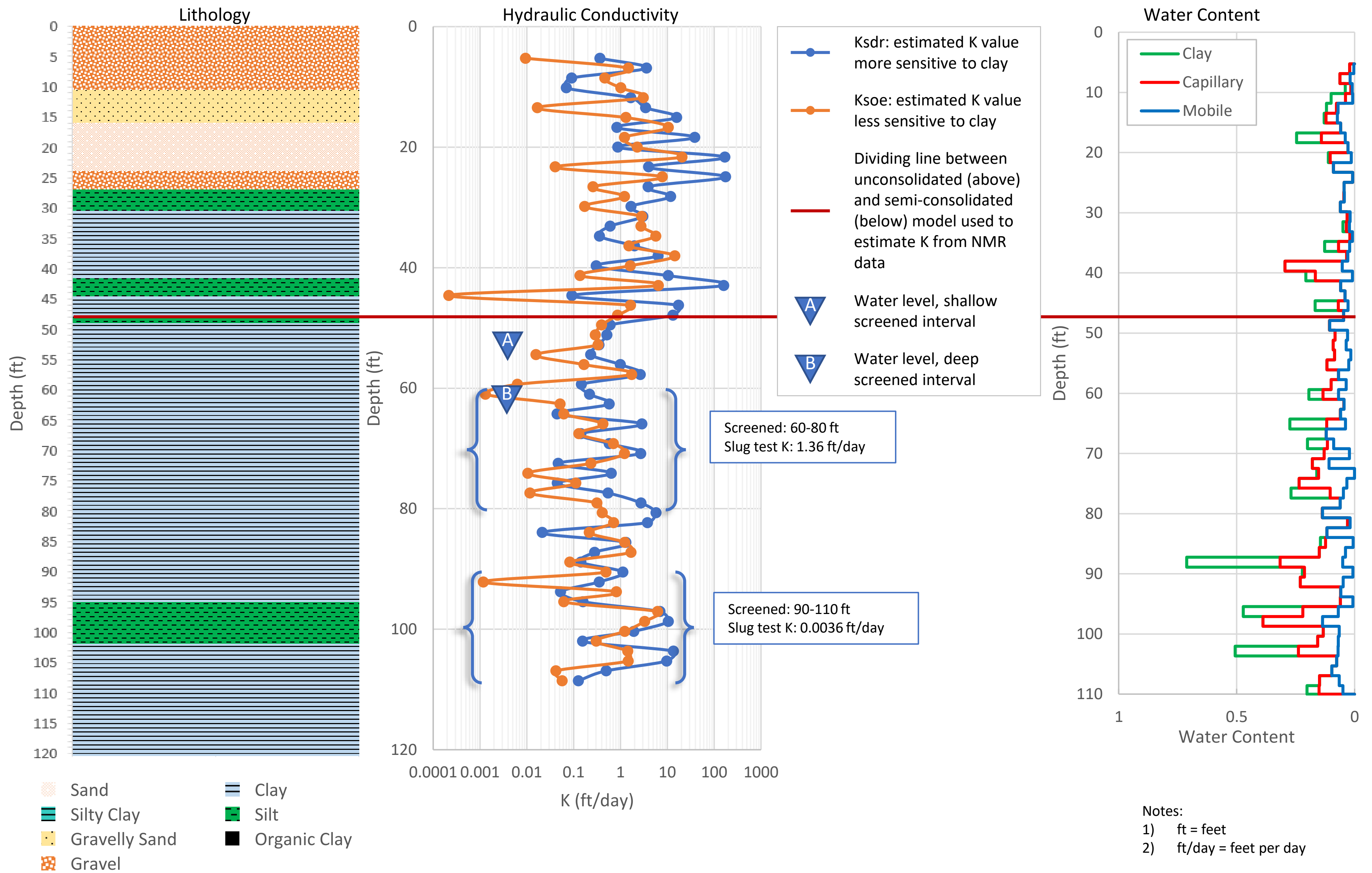
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MCF-06B_OUT1)

Initial Displacement: 0.975 ft
Total Well Penetration Depth: 26.99 ft
Casing Radius: 0.1667 ft

Static Water Column Height: 26.99 ft
Screen Length: 15. ft
Well Radius: 0.3333 ft

Attachment A.2
Nuclear Magnetic Resonance Logging Profiles



Notes:
1) ft = feet
2) ft/day = feet per day

TETRA TECH
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Phone: (702) 854-2293

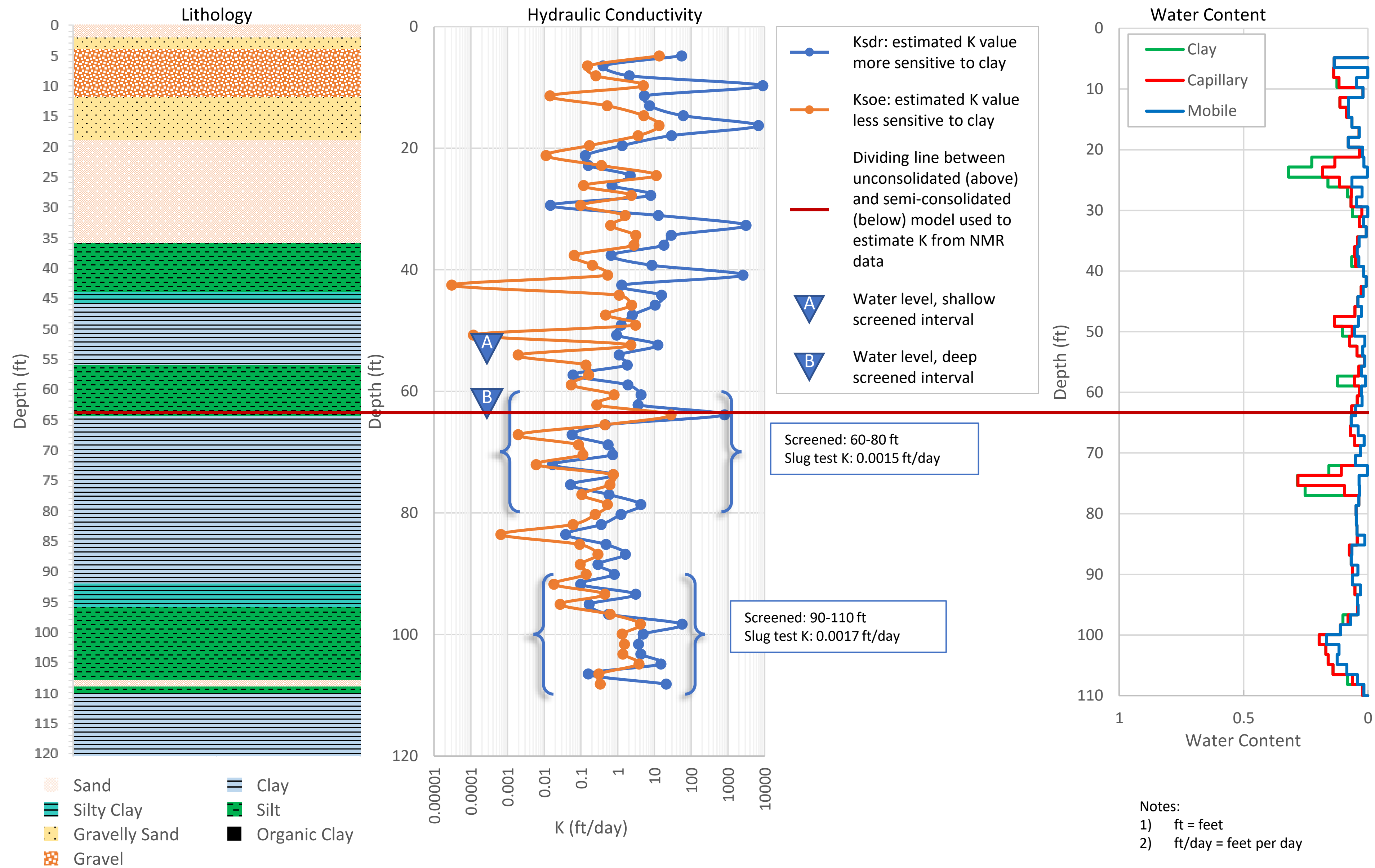
NEVADA ENVIRONMENTAL RESPONSE TRUST SITE

GALLERIA ROAD BIOREMEDIATION TREATABILITY STUDY
HENDERSON, NEVADA

SUMMARY OF NUCLEAR MAGNETIC RESONANCE LOGGING AND AQUIFER TEST RESULTS FOR GRTS-MW01A/B

Project No.:	117-7502018
Date:	AUGUST 27, 2018
Designed By:	ACC

Figure No.
1



Notes:
1) ft = feet
2) ft/day = feet per day

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NEVADA ENVIRONMENTAL RESPONSE TRUST SITE

GALLERIA ROAD BIOREMEDIATION TREATABILITY STUDY
HENDERSON, NEVADA

SUMMARY OF NUCLEAR MAGNETIC RESONANCE LOGGING AND AQUIFER TEST RESULTS FOR GRTS-MW02A/B

Project No.:	117-7502018
Date:	AUGUST 27, 2018
Designed By:	ACC
Figure No.	2

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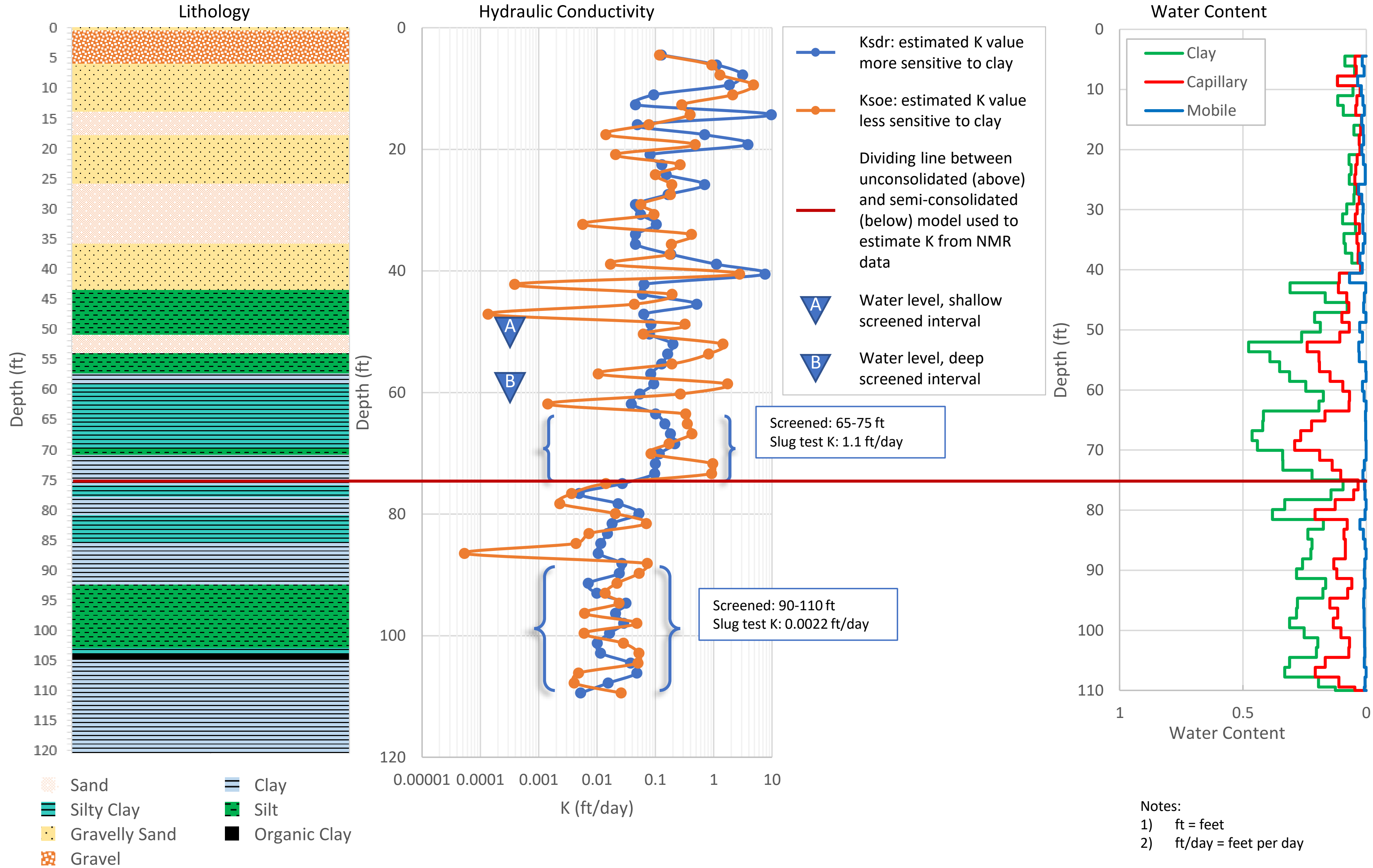

Notes:
1) ft = feet
2) ft/day = feet per day

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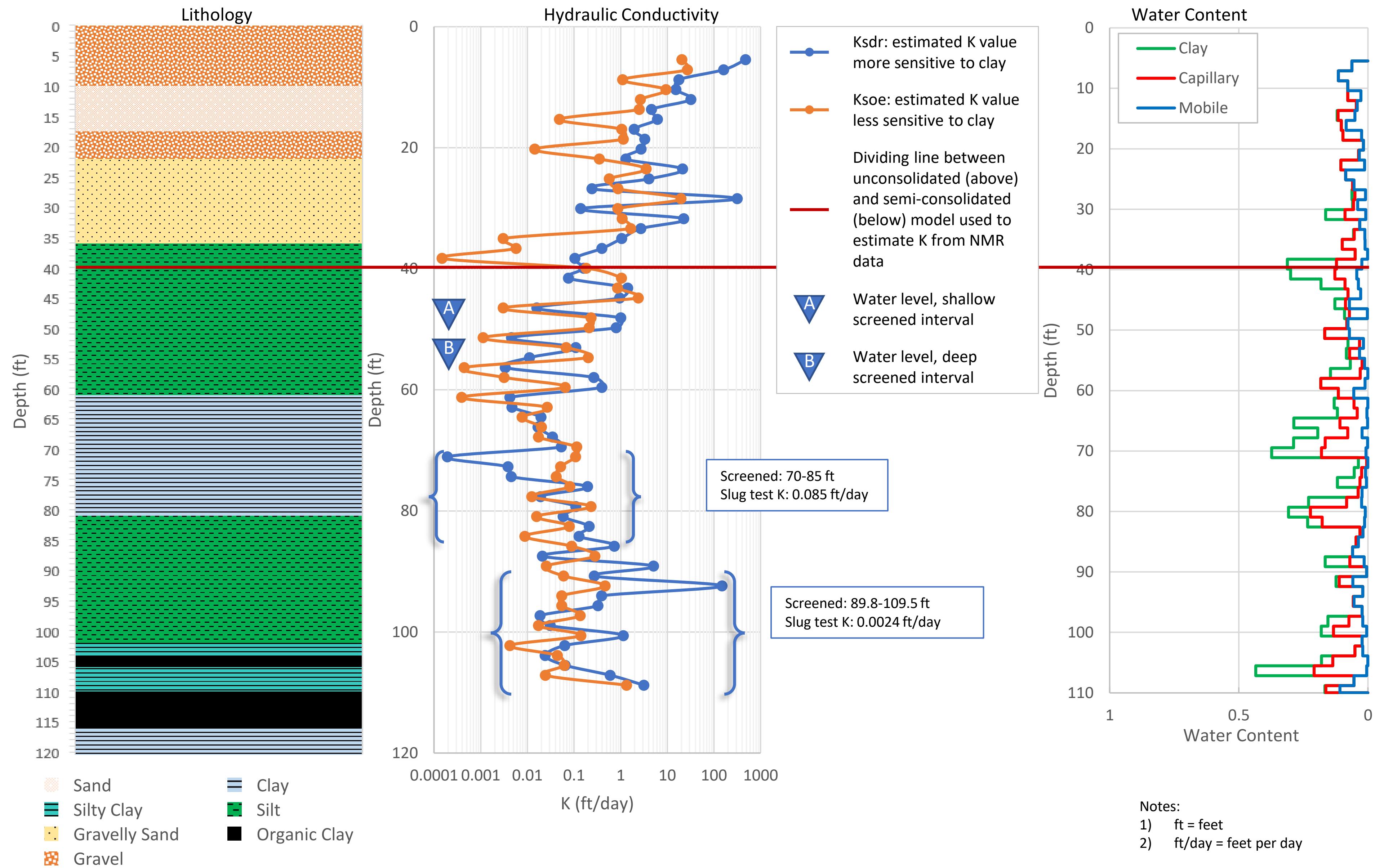
SUMMARY OF NUCLEAR MAGNETIC RESONANCE LOGGING AND AQUIFER TEST RESULTS FOR GRTS-MW03A/B

Project No.:	117-7502018
Date:	AUGUST 27, 2018
Designed By:	ACC

Figure No.
3



Notes:
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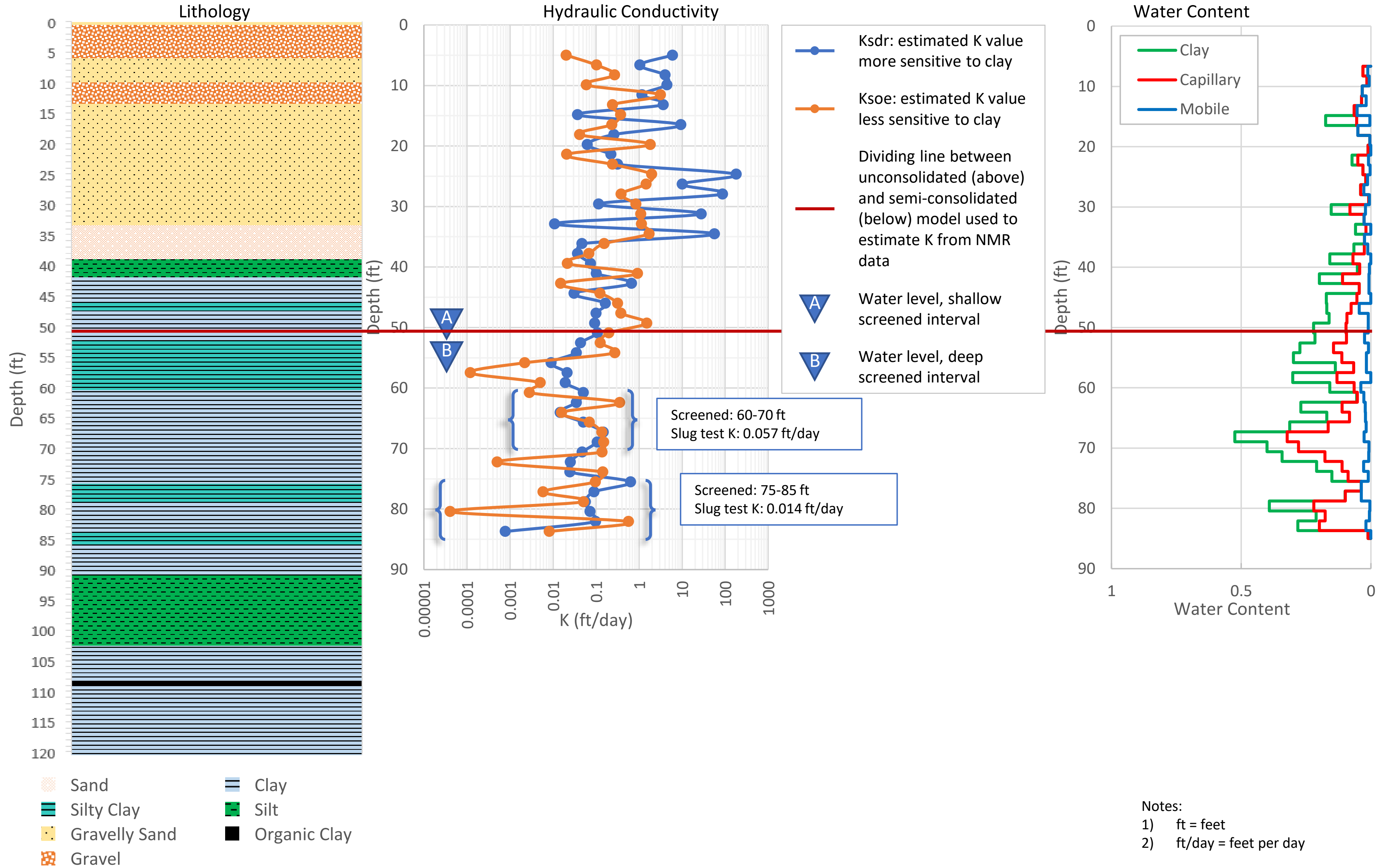
SUMMARY OF NUCLEAR MAGNETIC RESONANCE LOGGING AND AQUIFER TEST RESULTS FOR GRTS-MW04A/B

Project No.:	117-7502018
Date:	AUGUST 27, 2018
Designed By:	ACC

Figure No.
4



Notes:
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SUMMARY OF NUCLEAR MAGNETIC RESONANCE LOGGING AND AQUIFER TEST RESULTS FOR GRTS-MW05A/B

Project No.:	117-7502018
Date:	AUGUST 27, 2018
Designed By:	ACC
Figure No.	5

Attachment B
Injection Fracture Pressure Calculations

NEVADA ENVIRONMENTAL RESPONSE TRUST
GALLERIA ROAD BIOREMEDIATION TREATABILITY STUDY
INJECTION PRESSURE CALCULATION

The injection pressure which assumes that fractures are not initiated in the subsurface has been calculated using the theoretical fracture initiation pressure equations based on Jaworski et. Al. (1981), instead of the more general formula provided in the Nevada Administrative Code Section 445A.911. This theoretical fracture initiation pressure is a recognized method for computing fracture pressure when site-specific data is available, as is the case here for soil unit weight and other factors, as shown below. The maximum injection pressure at the well head is calculated as detailed below.

Fracture initiation pressure in clay, $P_f = m * \sigma_o + \sigma_{ta}$

Source: Jaworski, G. W., Seed, H. B., and Duncan, J. M. (1981). "Laboratory study of hydraulic fracturing." J. Geotech. Engrg. Div., 107(6), 713–732.

Where:

m-factor = empirical factor = 1.5

The m-factor ranges from 1.5 to 1.8 for silt and 1 to 2 for clays, where a factor of one is for cracked soil, which are not present at this site. Since the material ranges from silt to clay and the lowest value for silt is 1.5 and that same value is also a conservative value for uncracked soil, an overall factor of 1.5 is conservative for the m-factor.

σ_o = overburden pressure = $\gamma * D * K$
- γ, soil unit weight (pounds per cubic foot [pcf])
- D, depth, in feet
- K=1.0 for clay, no friction

K=1.0 applies to clays having no friction. Higher friction from silts and sands would result in higher K and higher permissible pressures. Therefore, a value of 1.0 is used conservatively for this calculation.

σ_{ta} = tensile strength of clay, conservatively assume = 0

Estimate Depth Hydraulic Fracture Pressure Using Literature Values for Material Combined with Site Specific Water Content Values

Approximate soil unit weight=	117.0	lbs/ft^3	Overburden comprises an upper 40-foot thick zone of sand and gravel, estimated to have a dry bulk unit weight on the order of 115 lbs/ft^3. The underlying clays and silts are estimated to have dry unit weight on the order of 90-100 lbs/ft^3, but are predominantly saturated with an approximate total unit saturated weight on the order of 120 lbs/ft^3. Using these estimates, an average unit weight of 117 lbs/ft^3 is estimated for the overburden soils.
Top of injection screen interval =	90	Feet below ground surface (20-feet of screen).	
P_f =	109.7	psi	Fracture pressure.
Elevation head, h_f = length of solid riser * unit weight of water	39.0	psi	Based on 90 feet of water in the solid injection well riser pipe above the screen. Unit weight of water = 62.4 lbs/ft^3.
Net pressure = $P_f - h_f$	70.7	psi	Net pressure measured at the ground surface to induce fracturing.

Based on the above calculations for the 90 - 110 ft bgs interval, the maximum planned injection pressure will be 60 psi.

This will provide a safety factor of : 1.1 **for this interval**