HYDROGEOLOGIC INVESTIGATION OF THE PROPOSED EASTERN UPLAND UNDERGROUND INFILTRATION GALLERY BLACK BUTTE COPPER PROJECT MEAGHER COUNTY, MT

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March 2017
Revised October 2017

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HYDROGEOLOGIC INVESTIGATION OF THE PROPOSED EASTERN UPLAND UNDERGROUND INFILTRATION GALLERY BLACK BUTTE COPPER PROJECT MEAGHER COUNTY, MT

1.0 INTRODUCTION

This report is an update of the March 2017 report to provide tracer monitoring results through September 2017 and additional analysis on the connectivity of the Eastern Underground Infiltration Gallery (UIG). Additional information is included in the following Sections:

- Section 3.2 – Additional discussion on the mounding observed in the monitoring wells adjacent to the infiltration pit.
- Section 3.4 – Provide additional data from ongoing tracer monitoring and a comprehensive discussion of the results of the tracer tests to date.
- Section 4.0 – New section that provides additional analysis of the tracer monitoring results. Aquifer properties analyses of mounding during infiltration were moved to this section.
- Section 5.0 – Updated summary of results based on additional data and analysis.

Hydrometrics, Inc. conducted an investigation of the groundwater system in the vicinity of the proposed eastern upland UIG. The purpose of this assessment was to characterize the groundwater system beneath the UIG, including determining the depth at which the local water table exists, assess the potential connection between infiltrated water to adjacent surface water bodies, and establish baseline water quality.

The scope of this assessment consisted of installation of two monitoring wells in the vicinity of the proposed eastern UIG, aquifer testing, infiltration testing with the addition of a tracer slug, tracer monitoring, and groundwater monitoring. A brief description of the methods used for each task and the results and analysis of the dye tracer investigation are summarized in Sections 2.0 through 4.0.

1.1 SITE BACKGROUND

The Black Butte Copper Project is located approximately 16 miles north of White Sulphur Springs, Montana in Meagher County (Figure 1). The project is in the stage of permitting to mine an underground copper deposit and is currently collecting baseline data for use in project development. The ore body consists of a sediment-hosted massive sulfide deposit within the mid-Proterozoic Newland Formation of the Belt Supergroup. The Newland Formation can be divided into a lower member that consists of primarily dolomitic shale and an upper member of interstratified shales and carbonates (Nelson, 1963).

Tintina plans to discharge treated water to two upland UIGs and one alluvial UIG. The two upland UIGs will have a combined capacity to infiltrate treated water of approximately 2,640 gpm. The annual average discharge rate is projected to be 398 gpm and a maximum discharge rate of 560 gpm. Water discharged to the three UIGs will be treated to meet non-degradation standards under an MPDES permit. Construction of the UIGs consists of excavating trenches approximately 3 feet wide and 4 to 6 feet deep (below the frost line). The HDPE pipe will be welded, perforated, and laid in the trenches in areas where subsurface infiltration is desired. The trench will be backfilled with approximately 8 to 12 inches of washed gravel, the pipe, approximately 3 inches of washed gravel above the pipe, and filter fabric or plastic screen over the gravel, separating the gravel and pipe from the overlying soil backfill material.

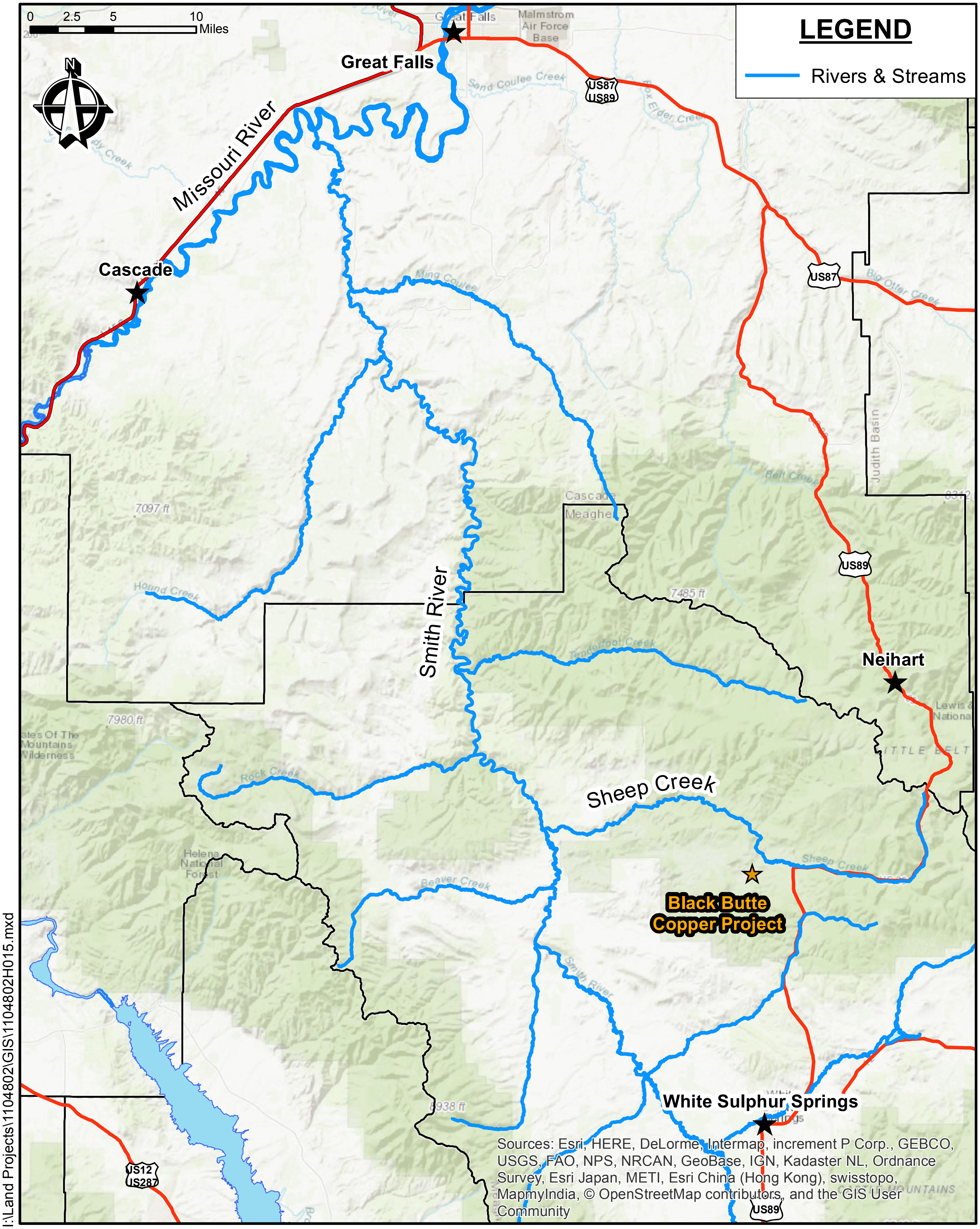

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Figure 1
Project Location Map
Black Butte Copper Project
Meagher County, Montana

2.0 HYDROGEOLOGIC INVESTIGATION

Hydrometrics commenced the eastern UIG hydrogeological investigation in September 2016 and continues to conduct tracer monitoring at surrounding surface water sources. The field investigation and methods used for well installation, aquifer testing, infiltration tracer testing, tracer monitoring, and water quality analyses are described in Sections 2.1 through 2.5, respectively.

2.1 WELL INSTALLATION

Two wells were installed and tested as part of this investigation; one in the northern portion of the eastern UIG (MW-14) and one near the southern portion of the eastern UIG (MW-15). The locations of the monitoring wells are shown on Figure 2. O'Keefe Drilling Company, Inc. was contracted to drill the wells using dual rotary drilling techniques. All drilling was supervised by a qualified scientist and detailed lithologic and construction logs were recorded on field forms and in a project field book. Well locations and measuring point elevations were surveyed by WWC Engineering the week of October 17, 2016. Well completion details are described in Section 3.1 of this report.

2.2 AQUIFER TESTING

Pneumatic slug tests were conducted on both wells to estimate the hydraulic conductivity of the units within the proposed Eastern UIG. The methods of the aquifer testing are summarized below and the results are summarized in Section 3.2 of this report.

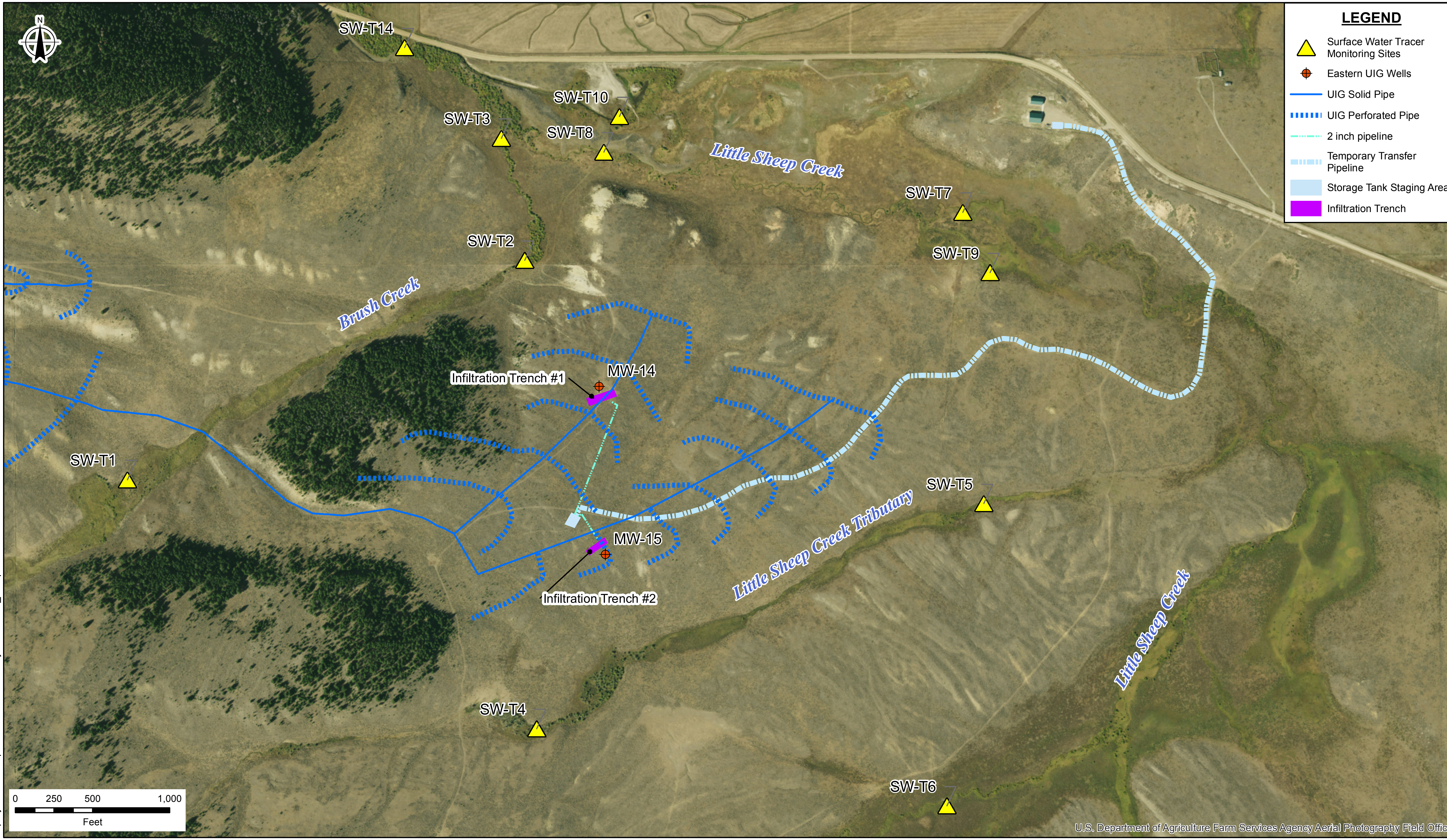

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Figure 2
UIG INFILTRATION TRACER TEST LAYOUT
Black Butte Copper Project
Meagher County, Montana

Pneumatic Slug Test: A pneumatic slug test uses air pressure to depress the water in a well, and then instantaneously releases the air, allowing the water level to recover at a rate proportional to the hydraulic conductivity of the aquifer in the vicinity of the well. The recovery of the water level is monitored to determine the hydraulic conductivity of the aquifer. Below is a summary of the procedures used to conduct pneumatic slug testing at the Black Butte Copper Site:

1. The static water level was measured and compared to the screened interval to determine the amount of water above the well screen.
2. A pneumatic slug test apparatus was used to seal the well and control the pressure in the well throughout the test.
3. The well was instrumented with a pressure transducer set at a depth below the proposed water level displacement; the transducer cable was sealed with a rubber gasket where it passed through the pneumatic slug test apparatus.
4. The transducer was set to record water levels at a one second interval or less prior to pressurizing the well.
5. The well was then pressurized using a compressor, which forced the water level downward in the well.
6. The pressure applied to the well was monitored using a pressure gauge that displayed the pressure placed on the wellhead (measured in inches of water).
7. The water level was allowed to stabilize at an elevation above the top of the well screen so that the injected air would not escape from the well via the screen.
8. Once the pressure applied to the well and the transducer readings were stable, the air was then released from the well through a 4-inch diameter ball valve resulting in an instantaneous change in pressure in the well.
9. The water level displacement was recorded with a Solinst-Levelogger pressure transducer.

Multiple tests were conducted to ensure reproducible results; the water level was allowed to fully recover prior to conducting subsequent tests.

2.3 INFILTRATION TRACER TESTING

Infiltration tracer tests were conducted near each of the two eastern UIG monitoring wells in October 2016. Infiltration Trench #1 is associated with well MW-14 and Infiltration Trench #2 is associated with well MW-15 (Figure 2). The tests were designed to simulate two times the discharge per linear foot of trench for the UIGs and to evaluate the connection between infiltrated water and surface water bodies proximal to the proposed Eastern UIG. Tintina is proposing to discharge an average of 398 gpm from the water treatment plant to the UIG. Collectively, the proposed UIGs are designed to have approximately 17,600 linear feet of perforated HDPE and have the combined capacity to infiltrate 2,640 gpm, approximately 6.6 times the proposed average discharge. Assuming a minimum of 3,000 linear feet of UIG will be active at one time, the discharge rate of the active UIG will be 0.13 gpm per linear foot of perforated pipe.

The two trenches were excavated to approximately 6 feet deep, 20 feet long at their base, and 3 feet wide to simulate the proposed excavation for the UIG trenches. The trenches were excavated approximately 10 feet upslope from each monitoring well, and between the infiltration trench and the nearest surface water resource.

To facilitate the infiltration, three 21,000-gallon storage tanks were set up on the site; one lower storage tank, located at the core shed, and two upper storage tanks located on the staging pad near MW-15 (Figure 2). Water was pumped from the exempt well (located at the core shed) into the lower storage tank, then pumped using a Dri-Prime pump through a transfer line, which consisted of 4-inch HDPE pipe and 4- and 6-inch galvanized steel pipe, to the upper storage tanks. Water from the upper storage tanks was gravity fed to the infiltration trenches through two-inch HDPE pipe (the water quality of the exempt well meets all DEQ-7 groundwater quality standards and is deemed appropriate for discharge). The transfer line was surveyed each time water was pumped to the upper tanks to monitor for leaks and assure no water discharged to surface water. The discharge rate was monitored using two SeaMetrics data logging flow meters. The discharge rate for infiltration test was designed to be six gpm, which is approximately 2.3 times the combined design capacity of the proposed UIGs (20 linear feet x 0.13 gpm/linear foot x 2.3 = 6 gpm). The increased discharge rate is intended to account for the limited area being tested compared to the proposed UIG area and allow for a conservative evaluation of the connection to surface water.

The infiltration tests were conducted by infiltrating water during a seven day period (October 4 through October 10, 2016). Slugs of dye tracers (fluorescein and eosine) were added to each infiltration trench on the fourth day of infiltration (October 7, 2016), and infiltration of water (without tracer) continued for three days afterward. This schedule allowed for a saturated front and groundwater mounding to develop beneath the infiltration trenches and promote transport of the tracer slug. The duration of the tracer slug intended to simulate the duration at which the treated discharge water is estimated to cycle through the proposed UIG. Water level monitoring was conducted at wells MW-14 and MW-15 throughout the infiltration test to monitor groundwater mounding and continues throughout tracer monitoring.

A separate dye was selected for each infiltration trench to evaluate connectivity between groundwater at two locations within the Eastern UIG and nearby surface water bodies. Fluorescent dyes (Fluorescein: Acid Yellow 73, color index 45350 and Eosine: Acid Red 87, color index 45380) were used as the tracers for the infiltration tests. Fluorescent tracer dyes are commonly used to assess the preferential flow paths, directly measure rate of flow, and verify subsurface connection between aquifers, streams, and springs. The dyes were provided in a powder form from Ozark Underground Laboratory (OUL) in Protem, Missouri. Each dye was independently mixed with a small volume of water in sealed 5-gallon carboys to ensure complete wetting, and to introduce the dye as a slug-type injection into the infiltration trenches. At each infiltration trench, the appropriate carboys were completely filled with groundwater from the 2-inch discharge lines, capped and oscillated to fully dissolve the dye powder in water. Five pounds of fluorescein dye (one 5-gallon carboy) were added to the southern infiltration trench (near MW-15) and ten pounds of dye (two 5-gallon carboys) were added to the northern infiltration trench (near MW-14) on October 7, 2016. The dye tracers were introduced to the infiltration trenches in such a manner to control the point of contact of the dye and simulate a slug-type injection. Extreme care was exercised to prevent cross-contamination of the dyes during transportation, mixing, and introduction.

After the assessment of preliminary tracer results and observations of site conditions (described in Section 3.0), a third dye tracer (Rhodamine WT: Acid Red 388) was injected directly to monitoring wells MW-14 and MW-15 on January 26, 2017. Two carboys (one for each well) with 20 pounds (40 pounds total) of pre-mixed rhodamine dye were provided by OUL. The rhodamine was pumped from the carboys into the screened interval of each well using a peristaltic pump and tubing.

2.4 TRACER MONITORING AND ANALYSES

Background monitoring consisted of deploying activated carbon sampler packets at the monitoring locations on September 19, 2016 and retrieving the packets and collection of grab samples of water on September 29, 2016, prior to the tracer being introduced to the infiltration trenches. Ongoing tracer monitoring is being conducted according to the schedule in Table 1 at surface water and groundwater monitoring sites as shown on Figure 2 and listed in Table 2. During tracer monitoring field activities on October 28, 2016, a groundwater seep located near Little Sheep Creek (SW-T9) was identified to be issuing from bedrock. Due to its proximity to the eastern UIG, the spring was instrumented with an activated carbon packet on November 4, 2016 and added to the tracer monitoring program. Two other sites (SW-T10 and SW-T14) were added to the monitoring program in the proximity of the groundwater discharging from the former gravel pit located north of Little Sheep Creek on January 25, 2017. Site SW-T10 is located in a channelized section of the gravel pit discharge and site SW-T14 is located below the confluence of Little Sheep Creek and the discharge from the gravel pit.

TABLE 1. MONITORING PERIOD DESCRIPTION AND SAMPLING INTERVALS

Monitoring Period	Sampling Interval
October 7 – November 7	Weekly
November 7 – April 7	Bi-weekly
April 7 – July 7	Bi-weekly*
July 7 – October 7	Monthly

*Extended bi-weekly sampling during spring thaw.

TABLE 2. MONITORING SITE DESCRIPTION AND ANALYSES

Site ID	Source Water	Location Description	Tracer Analysis
Surface Water Sites			
SW-T1	Brush Creek	Upgradient site on Brush Creek, southwest of infiltration trench	Eosine/Fluorescein/ Rhodamine WT
SW-T2	Brush Creek	Downgradient site on Brush Creek, northwest of Infiltration trench	Eosine/Fluorescein/ Rhodamine WT
SW-T3	Brush Creek	Downgradient site on Brush Creek, north/northwest of Infiltration trench	Eosine/Fluorescein/ Rhodamine WT
SW-T4	Little Sheep Crk Trib	Upgradient site on Little Sheep Creek Trib., south of infiltration trench	Eosine/Fluorescein/ Rhodamine WT
SW-T5	Little Sheep Crk Trib	Downgradient site on Little Sheep Creek Trib., east of infiltration trench	Eosine/Fluorescein/ Rhodamine WT
SW-T6	Little Sheep Creek	Upgradient site on Little Sheep Creek, southeast of infiltration trench	Eosine/Fluorescein/ Rhodamine WT
SW-T7	Little Sheep Creek	Downgradient site on Little Sheep Creek, north/northeast of infiltration trench	Eosine/Fluorescein/ Rhodamine WT
SW-T8	Little Sheep Creek	Downgradient site on Little Sheep Creek, north/northwest of infiltration trench	Eosine/Fluorescein/ Rhodamine WT
SW-T9*	Lowry Spring	Downgradient site near Little Sheep Creek, north/northeast of infiltration trench	Eosine/Fluorescein/ Rhodamine WT
SW-T10*	Gravel Pit Outfall	Approximately 100 feet downstream of culvert at gravel pit outfall, northwest of infiltration trench	Eosine/Fluorescein/ Rhodamine WT
SW-T14*	Little Sheep Creek	Downstream of the confluence with Brush Creek, at the location of SW-14, northwest of infiltration trench	Eosine/Fluorescein/ Rhodamine WT
Groundwater Sites			
MW-14	Groundwater	Adjacent to northern infiltration trench	Eosine/Fluorescein/ Rhodamine WT
MW-15	Groundwater	Adjacent to southern infiltration trench	Eosine/Fluorescein/ Rhodamine WT

*Monitoring site added on 11/04/16 (SW-T9) and 01/25/17 (SW-T10 and SW-T14).

Monitoring at sampling locations consists of the deployment of activated carbon packets (2-inch by 4-inch fiberglass screen packets partially filled with approximately 4.25 grams of activated carbon) that are capable of adsorbing and retaining the fluorescent tracer dye for a given sample period. Activated carbon packets continuously adsorb and accumulate the tracer dye to maximize its detection and minimize the number of samples needed for a given dye tracer test. The packets are securely anchored in the stream channel in duplicate pairs, anchored separately, and placed in a manner that would expose as much of the packet to flowing water as possible, and were suspended at the screened interval of the monitoring wells within in a perforated PVC capsule (prior to the Rhodamine WT injection). During each sampling event, the deployed activated carbon packets are collected in conjunction with grab samples of water (to provide data on the concentrations of dye in surface water or groundwater), and new activated carbon packets are subsequently deployed. The carbon packets and water samples are stored in a cooler immediately after collection to limit their exposure to light. Activated carbon packets and grab water samples remain in Hydrometrics' custody prior to being shipped to OUL with a completed chain-of-custody form.

For surface water monitoring sites, monitoring of dye tracers places primary reliance on activated carbon sampler packets and secondary reliance on grab samples of water. Water samples are only analyzed if dye is found to be present in the activated carbon sampler(s) and quantification of dye concentration is needed. If the site is found to be frozen or dry between consecutive sampling events and conditions suggest the packets have not been inundated in water, the activated carbon packets were not collected. For dye tracer monitoring in wells MW-14 and MW-15, dye tracer monitoring was similar to surface water sites until January 26, 2017 when the rhodamine dye was injected into the wells. Prior to rhodamine injection, the PVC capsules and sampler packets were removed from the wells and thereafter sole reliance is placed on grab samples of water.

The activated carbon packets and grab samples of water are submitted to OUL for analysis of the presence of fluorescein, eosine, and rhodamine WT dyes, as shown in Table 1. Only one packet is analyzed for all dyes from each sampling location. If a dye is detected on a sampler packet, the second packet from the site and event will be analyzed for confirmation and/or the grab sample will be analyzed to quantify concentration. If dye is detected during multiple monitoring events, Tintina may choose to discontinue monitoring after consultation with OUL and Montana Department of Environmental Quality (MDEQ).

2.5 WATER QUALITY SAMPLING AND ANALYSES

Groundwater monitoring was conducted at the wells MW-14 and MW-15 during the November 2016 monthly monitoring event. Water quality monitoring consisted of collection of field parameters and water quality samples from each well. The collection of groundwater samples generally consist of the following three steps:

1. Measurement of static water level;
2. Well purging and monitoring for field parameter stabilization; and
3. Water quality sample collection.

2.5.1 Static Water Level Measurement

Prior to collection of samples or removal/introduction of any equipment into the well, the static water level was measured at each well using an electric water level probe to determine the depth of groundwater below a specified measuring point (top of PVC well casing). Water level measurements were combined with surveyed measuring point elevations to compute groundwater elevations at each monitoring point.

2.5.2 Field Parameters and Water Quality Sample Collection

Field parameters and water quality samples were collected by installing a 2-inch Grundfos submersible pump and dedicated tubing to purge and sample wells MW-14 and MW-15. Adequate well purging is determined when three well-bore volumes have been removed and field parameters (pH, dissolved oxygen, temperature, specific conductance, and ORP) stabilize within the criteria specified in Table 3. Field instruments were calibrated according to factory instructions and calibration results are recorded on calibration forms. In the other three wells, samples for laboratory analysis were collected after a minimum of three well volumes had been removed and successive field parameter measurements agree to within the stability criteria given below.

TABLE 3. MONITORING SITE DESCRIPTION AND ANALYSES

Parameter (Units)	Stability Criteria
pH (standard units)	± 0.1 s.u.
Water temperature (°C)	± 0.2 °C
Specific conductance (μmhos/cm)	± 5% (SC ≤ 100 μmhos/cm) ± 3% (SC > 100 μmhos/cm)
Dissolved oxygen (mg/L)	± 0.3 mg/L

NOTE: Stability criteria obtained from USGS *National Field Manual for the Collection of Water Quality Data: Chapter A4, Collection of Water Samples* (September 1999).

Following well purging, final field parameter measurements were recorded, and groundwater quality samples were collected. Samples for trace constituents were filtered through a 0.45 μm filter prior to preservation to allow analysis for the dissolved fraction. Sample containers were rinsed three times with sample water prior to sample collection, then preserved as appropriate for the intended analysis (phosphoric acid preservation to pH <2 for nutrient analysis and nitric acid preservation to pH <2 for metals analysis), and stored on ice in coolers at approximately 4±2°C during transport.

The Grundfos pump was thoroughly decontaminated between uses according to the following procedure:

- Pump with approximately five gallons of soapy water (Alconox or other non-phosphate detergent); and
- Pump approximately five gallons of deionized water as a final rinse.

Water quality samples were submitted to Energy Laboratories in Helena, Montana for analysis of physical parameters, common ions, nutrients, and a comprehensive suite of trace constituents as listed in Table 4.

TABLE 4. ANALYTICAL METHODS AND DETECTION LIMITS FOR UIG MONITORING WELL SAMPLES TINTINA RESOURCES – BLACK BUTTE PROJECT

Parameter	Analytical Method(1)	Project-Required Detection Limit (mg/L)
Physical Parameters		
TDS	SM 2540C	10
TSS	SM2540C	10
Common Ions		
Alkalinity	SM 2320B	4
Sulfate	300.0	1
Chloride	300.0/SM 4500CL-B	1
Fluoride	A4500-F C	0.1
Calcium	215.1/200.7	1
Magnesium	242.1/200.7	1
Sodium	273.1/200.7	1
Potassium	258.1/200.7	1
Nutrients		
Nitrate+Nitrite as N	353.2	0.01
Trace Constituents (Dissolved(2))		
Aluminum (Al)	200.7/200.8	0.009
Antimony (Sb)	200.7/200.8	0.0005
Arsenic (As)	200.8/SM 3114B	0.001
Barium (Ba)	200.7/200.8	0.003
Beryllium (Be)	200.7/200.8	0.0008
Cadmium (Cd)	200.7/200.8	0.000003
Chromium (Cr)	200.7/200.8	0.01
Cobalt (Co)	200.7/200.8	0.01
Copper (Cu)	200.7/200.8	0.002
Iron (Fe)	200.7/200.8	0.02
Lead (Pb)	200.7/200.8	0.0003
Manganese (Mn)	200.7/200.8	0.005
Mercury (Hg)	245.2/245.1/200.8/SM 3112B	0.000005
Molybdenum (Mo)	200.7/200.8	0.002
Nickel (Ni)	200.7/200.8	0.001
Selenium (Se)	200.7/200.8/SM 3114B	0.0002
Silver (Ag)	200.7/200.8	0.02
Strontium (Sr)	200.7/200.8	0.0002
Thallium (Tl)	200.7/200.8	0.0002
Uranium	200.7/200.8	0.008
Zinc (Zn)	200.7/200.8	0.002
Field Parameters		
Stream Flow	HF-SOP-37/-44/-46	NA
Iron (II/III)[3]	HACH	0.1
Water Temperature	HF-SOP-20	0.1 °C
Dissolved Oxygen (DO)	HF-SOP-22	0.1 mg/L
pH	HF-SOP-20	0.1 s.u.
Specific Conductance (SC)	HF-SOP-79	1 µmhos/cm

(1) Analytical methods are from *Standard Methods for the Examination of Water and Wastewa*ter (SM) or EPA's *Methods for Chemical Analysis of Water and Waste* (1983).
(2) Samples to be analyzed for dissolved constituents will be field-filtered through a 0.45 µm filter.
(3) Arsenic will be analyzed on select samples as marked on the chain-of-custody.

3.0 FIELD INVESTIGATION RESULTS

3.1 WELL INSTALLATION

Monitoring well MW-14 and MW-15 both advanced through shale from surface to depth with variable thicknesses of shallow, weathered bedrock. The log for MW-14 shows approximately 25 feet of moderately weathered, variegated, silty shale overlying weakly-to-no weathered dark grey to black, weakly calcareous, thinly laminated shale, with intermittent intercepts of weathered fractures to 52.5 feet, and shear zones to depth. Water was first encountered at 56 feet during drilling. Monitoring well MW-15 shows a similar 20-foot intercept of weathered shale overlying comparable thinly laminated black shale with intermittent weathered fractures and shear zones to depth. Water in MW-15 was first encountered at 68 feet upon re-entry with an additional drilling rod. Both wells were completed in very fine to powdery broken shale, interpreted as a shear zone.

The two UIG monitoring wells were constructed with 2-inch ID (inside diameter) NFS-approved schedule 40 PVC with flush threaded joint couplings and 0.020-inch factory slotted screen. The borehole annulus was backfilled with silica sand from the well bottom to 3 to 4 feet above the top of the screen to provide a filter pack. The remainder of the borehole annulus was backfilled with bentonite chips to seal the borehole annulus and prevent fluid migration along the outer well casing. All wells were installed by a licensed monitoring well contractor and all construction and grouting details were consistent with State of Montana monitoring well construction regulations (ARM 36.21.800). Well completion details are summarized in Table 5 below and well logs are included in Appendix A.

TABLE 5. WELL COMPLETION DETAILS

Well Name	Northing (meters)	Easting (meters)	Ground Surface Elev. (feet, amsl)	Measuring Point Elev. (feet, amsl)	Total Depth (feet, bgs)	Screen Interval (feet, bgs)	Sand Pack Interval (feet, bgs)
	UTM Zone 12 North						
MW-14	5179376.766	508255.625	5761.16	5763.873	68	56-66	53-68
MW-15	5179071.066	508290.888	5795.26	5797.341	80	70-80	66-80

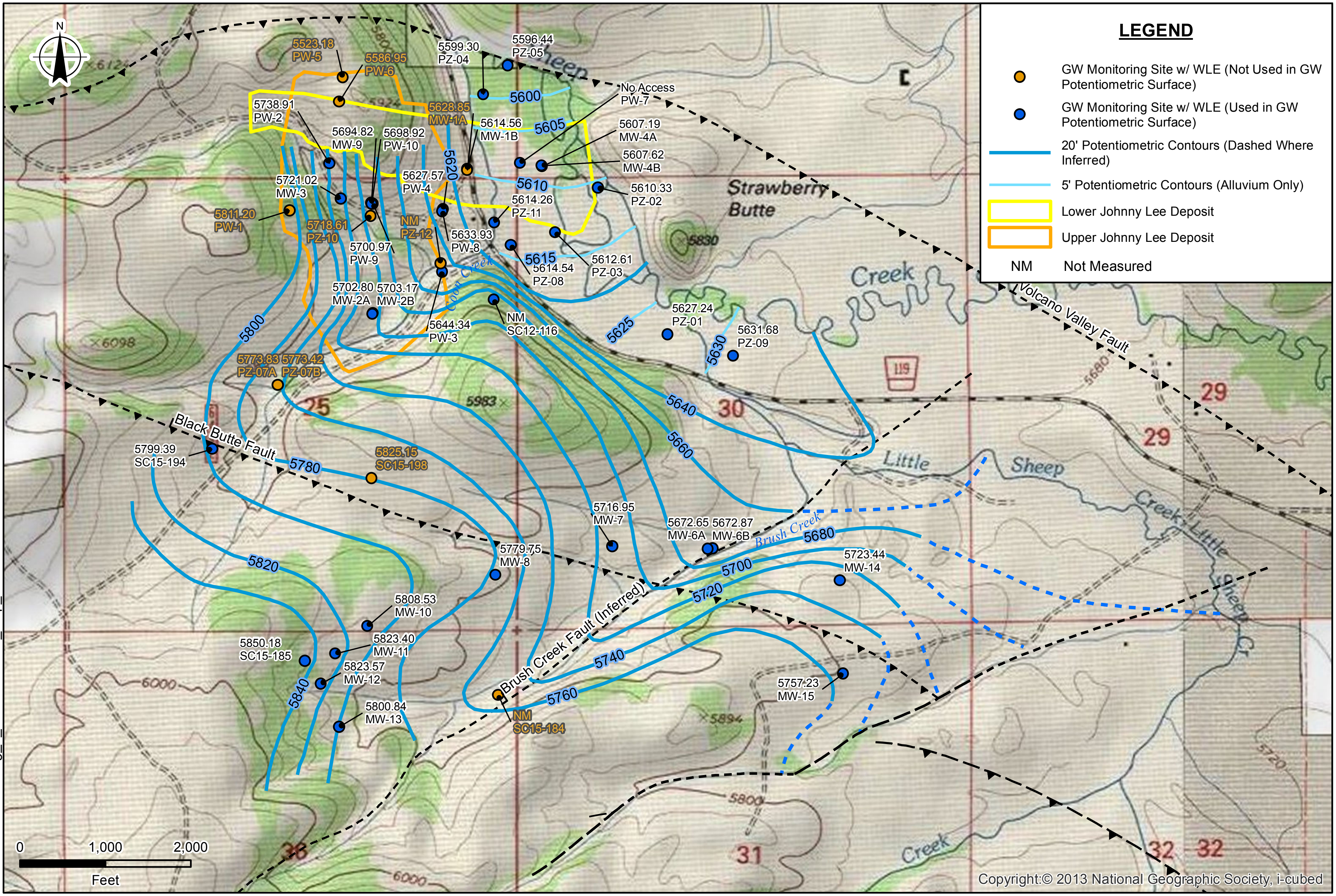
3.2 INFILTRATION TEST WATER LEVEL TRENDS

The water level elevation data collected during the 2016 fourth quarter groundwater sampling event was used to augment the project-scale potentiometric surface map, extending the coverage area to the eastern UIG (Figure 3). The potentiometric contours suggest a generally northeastern groundwater flow and a hydraulic gradient of approximately 0.03.

Water level data collected from the Easter UIG monitoring wells were used to monitor groundwater mounding due to infiltrating water in the two infiltration pits. Groundwater mounding was calculated as the difference between the pre-test static water level (9/21/16) and the subsequent water-level measurements during and after infiltration. The groundwater mound at wells MW-14 and MW-15 is shown in Figure 4. Water levels in both MW-14 and MW-15 appear to have a slightly decreasing trend prior to starting the infiltration test and following the infiltration test after the mound had dissipated. However, there is insufficient data to quantify the rate of water level decrease in either MW-14 or MW-15. A total of approximately 61,670 and 60,560 gallons of water were discharged at an average rate of 6.0 and 5.9 gpm to the infiltration trenches near MW-14 and MW-15, respectively. Water levels started to mound within two days after infiltration started near well MW-14 with a peak mound of 3.5 feet two days after infiltration had ceased. Mounding in MW-15 was less than MW-14 and based on pre-test water levels took longer to begin to mound. Groundwater levels at MW-15 started to mound above the initial water level measurement approximately three days after infiltration started and peaked at 1.0 feet two days after infiltration ceased. If it is assumed that the water levels were decreasing prior to the test and were near the post mounding water levels observed on December 6th and December 19th, mounding was observed within two days of the start of infiltration at both MW-14 and MW-15 and the maximum mound in the wells were about 1.5 feet and 4 feet, respectively.

3.3 SLUG TESTS

Two slug tests were attempted at each well due to the long recovery times required between each test. At well MW-14, only one successful slug test was conducted due to inadequate seal on the well, non-static conditions, and long recovery time. Slug test data were analyzed



V:\11048\GIS\UIG\Fig_4_Potentiometric_Map_V11.mxd

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Figure 3
November 2016 Potentiometric Surface Map
Black Butte Copper Project
Meagher County, Montana

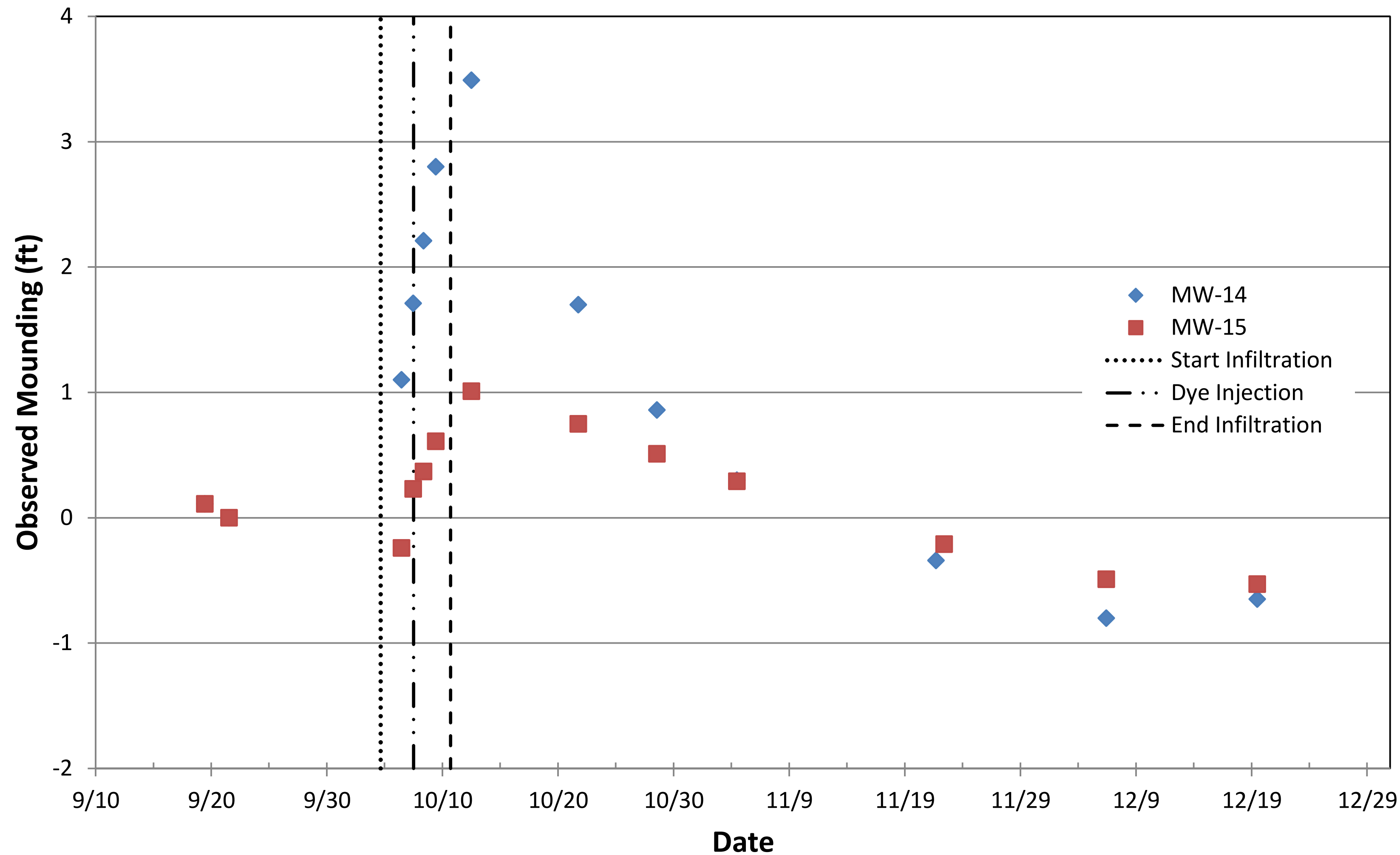

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Figure 4
Observed Mounding During Infiltration Test
Black Butte Copper Project
Meagher County, Montana

using AQTESOLV (v.4.5) to estimate aquifer hydraulic conductivities. The data were analyzed using the Bouwer-Rice (1976) straight line solution for slug tests. The results of the straight line analyses are summarized in Table 6 with curve matches included in Appendix B. The hydraulic conductivity estimates from the wells (MW-14 and MW-15) completed in Newland Formation shale ranged from 0.24 to 0.33 ft/day, which likely represent the permeability of non-weathered bedrock with minimal secondary permeability.

TABLE 6. SLUG TEST ANALYSIS HYDRAULIC CONDUCTIVITY RESULTS

Well ID	Hydraulic Conductivity (K) (ft/day)		
	Test 1	**Test 2**	**Average**
MW-14	0.33	NA	0.33
MW-15	0.24	0.25	0.25

3.4 TRACER MONITORING

Background tracer monitoring was conducted at the seven surface water monitoring stations and two monitoring wells on September 14, 2016. With the exception of one carbon packet from site SW-T1, none of the dyes used in the tracer analysis were detected in the background tracer monitoring (Table 7). At site SW-T1, the analysis from one of the carbon packets had a fluorescence peak present. However, the peak did not meet all of the criteria for a positive dye result. The laboratory reported the peak and calculated a tracer dye concentrations for both fluorescein and eosine. Due to the atypical peak wavelength the second carbon packet was used to verify the results from the initial analysis. There was no dye (fluorescein or eosine) detected on the second carbon packet from site SW-T1. Based on the atypical peak on the first packet and the non-detect on the second packet it was determined that there was no background (natural) fluorescein or eosine at site SW-T1.

A total of 20 monitoring events have been conducted following injection of the dyes into the infiltration trenches. Tracer monitoring included collection of both water samples and carbon packets. The water sample allow for grab samples to quantify dye concentrations in place and time; whereas the carbon packets allow for continuous monitoring for dye. No detectable eosine or fluorescein was detected in any of 221 samples collected from the monitoring wells, surface water, and groundwater seeps from October 2016 to September 2017 (Table 8). Additionally, tracer sampling did not show detectable rhodamine at any of the sites prior to the injection in MW-14 and MW-15, and no detections in surface water or groundwater seeps to date.

Following injection of the rhodamine into wells MW-14 and MW-15, detectable rhodamine was shown in both wells at very high concentrations. Concentrations ranged between 136,000 and 119,000 ppb at MW-14 and between 226,000 and 45,400 ppb at MW-15 during the first month after injection. Rhodamine concentration remained highly elevated (about 40,000 to 90,000 ppb) through June 2017. The limited change in rhodamine concentration and low permeability of the lower portion of the aquifer indicate that the rhodamine injection to the wells is not representative to the transport of water that is discharged to the proposed UIGs. Therefore, the rhodamine testing in the wells was discontinued after June 15, 2017. Laboratory reports for the tracer monitoring are included in Appendix D.

TABLE 7. BACKGROUND TRACER MONITORING

Station Name	Date/Time Placed	Date/Time Collected	Fluorescein (ppm)	Eosine (ppm)	Rhodamine WT (ppm)
SW-1T	9/14/2016	9/29/2016	445	782	<1.7E-04
SW-1T Dup	9/14/2016	9/29/2016	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	9/14/2016	9/29/2016	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	9/14/2016	9/29/2016	<2.5E-05	<5.0E-05	<1.7E-04
SW-4T	9/14/2016	9/28/2016	<2.5E-05	<5.0E-05	<1.7E-04
SW-5T	9/14/2016	9/28/2016	<2.5E-05	<5.0E-05	<1.7E-04
SW-6T	9/14/2016	9/29/2016	<2.5E-05	<5.0E-05	<1.7E-04
SW-7T	9/14/2016	9/29/2016	<2.5E-05	<5.0E-05	<1.7E-04
SW-8T	9/14/2016	9/29/2016	<2.5E-05	<5.0E-05	<1.7E-04
MW-14	9/22/2016	9/28/2016	<2.5E-05	<5.0E-05	<1.7E-04
MW-15	9/22/2016	9/28/2016	<2.5E-05	<5.0E-05	<1.7E-04

Note: A fluorescence peak was present that does not meet all the criteria for a positive result. Concentration were calculated; however, the duplicate activated carbon packet did not have a fluorescein or eosine peak.

TABLE 8. SUMMARY OF TRACER MONITORING RESULTS

Station Name	Date Placed	Date Collected	Fluorescein (ppm)	Eosine (ppm)	Rhodamine WT (ppm)
SW-1T	9/29/2016	10/14/2016	<2.5E-05	<5.0E-05	--
SW-2T	9/29/2016	10/14/2016	<2.5E-05	<5.0E-05	--
SW-3T	9/29/2016	10/14/2016	<2.5E-05	<5.0E-05	--
SW-4T	9/28/2016	10/14/2016	<2.5E-05	<5.0E-05	--
SW-5T	9/28/2016	10/14/2016	<2.5E-05	<5.0E-05	--
SW-6T	9/29/2016	10/14/2016	<2.5E-05	<5.0E-05	--
SW-7T	9/29/2016	10/14/2016	<2.5E-05	<5.0E-05	--
SW-8T	9/29/2016	10/14/2016	<2.5E-05	<5.0E-05	--
MW-14	9/28/2016	10/12/2016	<2.5E-05	<5.0E-05	--
MW-15	9/28/2016	10/12/2016	<2.5E-05	<5.0E-05	--
SW-1T	10/14/2016	10/21/2016	<2.5E-05	<5.0E-05	--
SW-2T	10/14/2016	10/21/2016	<2.5E-05	<5.0E-05	--
SW-3T	10/14/2016	10/21/2016	<2.5E-05	<5.0E-05	--
SW-4T	10/14/2016	10/21/2016	<2.5E-05	<5.0E-05	--
SW-5T	10/14/2016	10/21/2016	<2.5E-05	<5.0E-05	--
SW-6T	10/14/2016	10/21/2016	<2.5E-05	<5.0E-05	--
SW-7T	10/14/2016	10/21/2016	<2.5E-05	<5.0E-05	--
SW-8T	10/14/2016	10/21/2016	<2.5E-05	<5.0E-05	--
MW-14	10/12/2016	10/21/2016	<2.5E-05	<5.0E-05	--
MW-15	10/12/2016	10/21/2016	<2.5E-05	<5.0E-05	--
SW-1T	10/21/2016	10/28/2016	<2.5E-05	<5.0E-05	--
SW-2T	10/21/2016	10/28/2016	<2.5E-05	<5.0E-05	--
SW-3T	10/21/2016	10/28/2016	<2.5E-05	<5.0E-05	--
SW-4T	10/21/2016	10/28/2016	<2.5E-05	<5.0E-05	--
SW-5T	10/21/2016	10/28/2016	<2.5E-05	<5.0E-05	--
SW-6T	10/21/2016	10/28/2016	<2.5E-05	<5.0E-05	--
SW-7T	10/21/2016	10/28/2016	<2.5E-05	<5.0E-05	--
SW-8T	10/21/2016	10/28/2016	<2.5E-05	<5.0E-05	--
MW-14	10/21/2016	10/28/2016	<2.5E-05	<5.0E-05	--
MW-15	10/21/2016	10/28/2016	<2.5E-05	<5.0E-05	--
SW-1T	10/28/2016	11/4/2016	<2.5E-05	<5.0E-05	--
SW-2T	10/28/2016	11/4/2016	<2.5E-05	<5.0E-05	--
SW-3T	10/28/2016	11/4/2016	<2.5E-05	<5.0E-05	--
SW-4T	10/28/2016	11/4/2016	<2.5E-05	<5.0E-05	--
SW-5T	10/28/2016	11/4/2016	<2.5E-05	<5.0E-05	--
SW-6T	10/28/2016	11/4/2016	<2.5E-05	<5.0E-05	--
SW-7T	10/28/2016	11/4/2016	<2.5E-05	<5.0E-05	--
SW-8T	10/28/2016	11/4/2016	<2.5E-05	<5.0E-05	--
MW-14	10/28/2016	11/4/2016	<2.5E-05	<5.0E-05	--
MW-15	10/28/2016	11/4/2016	<2.5E-05	<5.0E-05	--
SW-1T	11/4/2016	11/22/2016	<2.5E-05	<5.0E-05	--
SW-2T	11/4/2016	11/22/2016	<2.5E-05	<5.0E-05	--
SW-3T	11/4/2016	11/22/2016	<2.5E-05	<5.0E-05	--
SW-4T	11/4/2016	11/21/2016	<2.5E-05	<5.0E-05	--

TABLE 8. SUMMARY OF TRACER MONITORING RESULTS

Station Name	Date Placed	Date Collected	Fluorescein (ppm)	Eosine (ppm)	Rhodamine WT (ppm)
SW-5T	11/4/2016	11/21/2016	<2.5E-05	<5.0E-05	--
SW-6T	11/4/2016	11/21/2016	<2.5E-05	<5.0E-05	--
SW-7T	11/4/2016	11/21/2016	<2.5E-05	<5.0E-05	--
SW-8T	11/4/2016	11/22/2016	<2.5E-05	<5.0E-05	--
SW-9T	11/4/2016	11/21/2016	<2.5E-05	<5.0E-05	--
MW-14	11/4/2016	11/21/2016	<2.5E-05	<5.0E-05	--
MW-15	11/4/2016	11/22/2016	<2.5E-05	<5.0E-05	--
SW-1T	11/22/2016	12/6/2016	<2.5E-05	<5.0E-05	--
SW-2T	11/22/2016	12/6/2016	<2.5E-05	<5.0E-05	--
SW-3T	11/22/2016	12/6/2016	<2.5E-05	<5.0E-05	--
SW-4T	11/21/2016	12/6/2016	<2.5E-05	<5.0E-05	--
SW-5T	11/21/2016	12/6/2016	<2.5E-05	<5.0E-05	--
SW-6T	11/21/2016	12/6/2016	<2.5E-05	<5.0E-05	--
SW-7T	11/21/2016	12/6/2016	<2.5E-05	<5.0E-05	--
SW-8T	11/22/2016	12/6/2016	<2.5E-05	<5.0E-05	--
SW-9T	11/21/2016	12/6/2016	<2.5E-05	<5.0E-05	--
MW-14	11/21/2016	12/6/2016	<2.5E-05	<5.0E-05	--
MW-15	11/22/2016	12/6/2016	<2.5E-05	<5.0E-05	--
SW-1T	12/6/2016	12/19/2016	<2.5E-05	<5.0E-05	--
SW-2T	12/6/2016	12/19/2016	<2.5E-05	<5.0E-05	--
SW-3T	12/6/2016	12/19/2016	<2.5E-05	<5.0E-05	--
SW-4T	12/6/2016	12/19/2016	<2.5E-05	<5.0E-05	--
SW-5T	12/6/2016	12/19/2016	<2.5E-05	<5.0E-05	--
SW-6T	12/6/2016	12/19/2016	<2.5E-05	<5.0E-05	--
SW-7T	12/6/2016	12/19/2016	<2.5E-05	<5.0E-05	--
SW-8T	12/6/2016	12/19/2016	<2.5E-05	<5.0E-05	--
SW-9T	12/6/2016	12/19/2016	<2.5E-05	<5.0E-05	--
MW-14	12/6/2016	12/19/2016	<2.5E-05	<5.0E-05	--
MW-15	12/6/2016	12/19/2016	<2.5E-05	<5.0E-05	--
SW-1T	12/19/2016	1/10/2017	<2.5E-05	<5.0E-05	--
SW-2T	12/19/2016	1/10/2017	<2.5E-05	<5.0E-05	--
SW-3T	12/19/2016	1/10/2017	<2.5E-05	<5.0E-05	--
SW-4T	12/19/2016	1/10/2017	<2.5E-05	<5.0E-05	--
SW-5T	No sample collected, frozen or dry between consecutive sampling events				
SW-6T	12/19/2016	1/10/2017	<2.5E-05	<5.0E-05	--
SW-7T	12/19/2016	1/10/2017	<2.5E-05	<5.0E-05	--
SW-8T	12/19/2016	1/10/2017	<2.5E-05	<5.0E-05	--
SW-9T	12/19/2016	1/10/2017	<2.5E-05	<5.0E-05	--
MW-14	12/19/2016	1/11/2017	<2.5E-05	<5.0E-05	--
MW-15	12/19/2016	1/11/2017	<2.5E-05	<5.0E-05	--
SW-1T	1/10/2017	1/25/2017	<2.5E-05	<5.0E-05	--
SW-2T	1/10/2017	1/25/2017	<2.5E-05	<5.0E-05	--
SW-3T	No sample collected, frozen or dry between consecutive sampling events				
SW-4T	1/10/2017	1/25/2017	<2.5E-05	<5.0E-05	--

TABLE 8. SUMMARY OF TRACER MONITORING RESULTS

Station Name	Date Placed	Date Collected	Fluorescein (ppm)	Eosine (ppm)	Rhodamine WT (ppm)
SW-5T	No sample collected, frozen or dry between consecutive sampling events				
SW-6T	1/10/2017	1/25/2017	<2.5E-05	<5.0E-05	--
SW-7T	No sample collected, frozen or dry between consecutive sampling events				
SW-8T	No sample collected, frozen or dry between consecutive sampling events				
SW-9T	1/10/2017	1/25/2017	<2.5E-05	<5.0E-05	--
MW-14	1/11/2017	1/25/2017	<2.5E-05	<5.0E-05	--
MW-15	1/11/2017	1/25/2017	<2.5E-05	<5.0E-05	--
SW-1T	1/25/2017	2/10/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	1/25/2017	2/10/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	1/10/2017	2/10/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-4T	1/25/2017	2/10/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-5T	No sample collected, frozen or dry between consecutive sampling events				
SW-6T	1/25/2017	2/10/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-7T	No sample collected, frozen or dry between consecutive sampling events				
SW-8T	1/10/2017	2/10/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-9T	1/25/2017	2/10/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-10T	1/25/2017	2/10/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-14T	1/25/2017	2/10/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-1T	2/10/2017	3/3/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	2/10/2017	3/3/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	No sample collected, frozen or dry between consecutive sampling events				
SW-4T	2/10/2017	3/3/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-5T	No sample collected, frozen or dry between consecutive sampling events				
SW-6T	2/10/2017	3/3/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-7T	1/10/2017	3/3/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-8T	2/10/2017	3/3/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-9T	2/10/2017	3/3/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-10T	2/10/2017	3/3/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-14T	2/10/2017	3/3/2017	<2.5E-05	<5.0E-05	<1.7E-04
MW-14	Water	2/2/2017	<2.0E-06	<1.5E-05	1.36E+11
MW-14	Water	2/10/2017	<2.0E-06	<1.5E-05	1.23E+11
MW-14	Water	2/16/2017	<2.0E-06	<1.5E-05	1.31E+11
MW-14	Water	3/3/2017	<2.0E-06	<1.5E-05	1.19E+11
MW-15	Water	1/27/2017	<2.0E-06	<1.5E-05	2.26E+11
MW-15	Water	2/2/2017	<2.0E-06	<1.5E-05	4.54E+10
MW-15	Water	2/10/2017	<2.0E-06	<1.5E-05	8.23E+10
MW-15	Water	2/16/2017	<2.0E-06	<1.5E-05	5.65E+10
MW-15	Water	3/3/2017	<2.0E-06	<1.5E-05	5.94E+10
SW-1T	3/3/2017	3/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	3/3/2017	3/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	No sample collected, frozen or dry between consecutive sampling events				
SW-4T	3/3/2017	3/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-5T	No sample collected, frozen or dry between consecutive sampling events				
SW-6T	3/3/2017	3/17/2017	<2.5E-05	<5.0E-05	<1.7E-04

TABLE 8. SUMMARY OF TRACER MONITORING RESULTS

Station Name	Date Placed	Date Collected	Fluorescein (ppm)	Eosine (ppm)	Rhodamine WT (ppm)
SW-7T	3/3/2017	3/23/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-8T	3/3/2017	3/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-9T	3/3/2017	3/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-10T	3/3/2017	3/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-14T	3/3/2017	3/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-1T	3/17/2017	3/31/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	3/17/2017	3/31/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	2/10/2017	3/31/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-4T	3/17/2017	3/31/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-5T	12/19/2016	3/31/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-6T	3/17/2017	3/31/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-7T	3/23/2017	3/31/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-8T	3/17/2017	3/31/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-9T	3/17/2017	3/31/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-10T	3/17/2017	3/31/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-14T	3/17/2017	3/31/2017	<2.5E-05	<5.0E-05	<1.7E-04
MW-14	Water	3/31/2017	<2.0E-06	<1.5E-05	1.31E+11
MW-15	Water	3/31/2017	<2.0E-06	<1.5E-05	5.56E+10
SW-1T	3/31/2017	4/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	3/31/2017	4/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	3/31/2017	4/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-4T	3/31/2017	4/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-5T	3/31/2017	4/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-6T	3/31/2017	4/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-7T	3/31/2017	4/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-8T	3/31/2017	4/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-9T	3/31/2017	4/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-10T	3/31/2017	4/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-14T	3/31/2017	4/17/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-1T	4/17/2017	5/4/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	4/17/2017	5/4/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	4/17/2017	5/4/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-4T	4/17/2017	5/4/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-5T	4/17/2017	5/4/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-6T	4/17/2017	5/4/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-7T	4/17/2017	5/4/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-8T	4/17/2017	5/4/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-9T	4/17/2017	5/4/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-10T	4/17/2017	5/4/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-14T	4/17/2017	5/4/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-1T	5/4/2017	5/22/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	5/4/2017	5/22/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	5/4/2017	5/22/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-4T	5/4/2017	5/22/2017	<2.5E-05	<5.0E-05	<1.7E-04

TABLE 8. SUMMARY OF TRACER MONITORING RESULTS

Station Name	Date Placed	Date Collected	Fluorescein (ppm)	Eosine (ppm)	Rhodamine WT (ppm)
SW-5T	5/4/2017	5/22/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-6T	5/4/2017	5/22/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-7T	5/4/2017	5/22/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-8T	5/4/2017	5/22/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-9T	5/4/2017	5/22/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-10T	5/4/2017	5/22/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-14T	5/4/2017	5/22/2017	<2.5E-05	<5.0E-05	<1.7E-04
MW-14	Water	5/4/2017	<2.0E-06	<1.5E-05	6.75E+10
MW-15	Water	5/4/2017	<2.0E-06	<1.5E-05	4.21E+10
SW-1T	5/22/2017	6/14/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	5/22/2017	6/14/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	5/22/2017	6/14/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-4T	5/22/2017	6/14/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-5T	5/22/2017	6/14/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-6T	5/22/2017	6/14/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-7T	5/22/2017	6/14/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-8T	5/22/2017	6/14/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-9T	5/22/2017	6/14/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-10T	5/22/2017	6/14/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-14T	5/22/2017	6/14/2017	<2.5E-05	<5.0E-05	<1.7E-04
MW-14	Water	6/15/2017	<2.0E-06	<1.5E-05	9.64E+10
MW-15	Water	6/15/2017	<2.0E-06	<1.5E-05	4.39E+10
SW-1T	6/14/2017	7/12/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	6/14/2017	7/12/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	6/14/2017	7/12/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-4T	6/14/2017	7/12/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-5T	6/14/2017	7/12/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-6T	6/14/2017	7/12/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-7T	6/14/2017	7/12/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-8T	6/14/2017	7/12/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-9T	6/14/2017	7/12/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-10T	6/14/2017	7/12/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-14T	6/14/2017	7/12/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-1T	7/12/2017	8/9/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	7/12/2017	8/9/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	7/12/2017	8/9/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-4T	7/12/2017	8/9/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-5T	7/12/2017	8/9/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-6T	7/12/2017	8/9/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-7T	7/12/2017	8/9/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-8T	7/12/2017	8/9/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-9T	7/12/2017	8/9/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-10T	7/12/2017	8/9/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-14T	7/12/2017	8/9/2017	<2.5E-05	<5.0E-05	<1.7E-04

TABLE 8. SUMMARY OF TRACER MONITORING RESULTS

Station Name	Date Placed	Date Collected	Fluorescein (ppm)	Eosine (ppm)	Rhodamine WT (ppm)
SW-1T	8/9/2017	9/6/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-2T	8/9/2017	9/6/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-3T	8/9/2017	9/6/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-4T	8/9/2017	9/6/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-5T	No sample collected, dry between consecutive sampling events				
SW-6T	8/9/2017	9/6/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-7T	8/9/2017	9/7/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-8T	8/9/2017	9/6/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-9T	8/9/2017	9/6/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-10T	8/9/2017	9/6/2017	<2.5E-05	<5.0E-05	<1.7E-04
SW-14T	8/9/2017	9/7/2017	<2.5E-05	<5.0E-05	<1.7E-04

Field observations in December 2016 and January 2017 indicated the monitoring sites on the lower reaches of Brush Creek, Little Sheep Creek, and the unnamed Tributary to Little Sheep Creek were completely frozen. However, the monitoring sites at the upper reaches were still flowing under ice and snow cover. On several occurrences, surface water monitoring sites SW-3T, SW-5T, SW-7T, and SW-8T have been frozen or dry between subsequent tracer monitoring events; therefore, samples were collected at dates specified in Table 8.

3.5 WATER QUALITY

Water quality results from MW-14 and MW-15 are shown in Table 9. Groundwater at the two wells are similar to other shallow wells in the area which are characterized as a calcium bicarbonate type water, near neutral pH, and specific conductance ranging from 464 to 498 µmhos/cm. Dissolved metals concentrations were all below the human health standard and dissolved trace constituent concentrations were below or near the detection limit at both wells. Trace constituents detected in MW-14 and MW-15 above the reporting limit includes dissolved aluminum, arsenic, barium, iron, manganese, strontium, and zinc. Water quality analytical results from well MW-14 report dissolved antimony, lead, molybdenum, nickel, and selenium above the reporting limit. The additional metals detected in MW-14 may be a result of the high suspended solids in the discharge from the well. Field water quality parameters collected at the tracer monitoring sites during each monitoring event are included in Table 10.

TABLE 9. NOVEMBER 2016 GROUNDWATER QUALITY DATA

STATION NAME	MW-14	MW-15	*Groundwater Human Health Standard*
Sample Date	11/18/2016	11/18/2016	
Field Sample Id	BBC-1611-326	BBC-1611-323	
FIELD PARAMETERS			
Depth To Water (ft)	40.43	40.11	-
pH – Field (s.u.)	7.65	7.45	-
Specific Conductance (µmhos/cm)	464	498	-
Temperature (C)	5.4	6.2	-
Dissolved Oxygen (mg/L)	0.49	0.38	-
PHYSICAL PARAMETERS (mg/L)			
Total Dissolved Solids	236	257	-
Total Suspended Solids	800	17	-
COMMON IONS (mg/L)			
Alkalinity as CACO3	360	230	-
Chloride	5.4	1.3	-
Fluoride	0.6	0.4	*4*
Sulfate	15	22	-
Total Hardness (Calculated)	226	257	-
Calcium (DIS)	41	47	-
Magnesium (DIS)	30	34	-
Potassium (DIS)	2	2	-
Sodium (DIS)	3	3	-
NUTRIENTS (mg/L)			
Nitrate + Nitrite as n	0.05	<0.01	*10*
DISSOLVED TRACE CONSTITUENTS (mg/L)			
Aluminum (DIS)	0.046	0.045	--
Antimony (DIS)	0.0008	<0.0005	*0.006*
Arsenic (DIS)	0.002	0.004	*0.01*
Barium (DIS)	0.06	0.051	*1*
Beryllium (DIS)	<0.0008	<0.0008	*0.004*
Cadmium (DIS)	<0.00003	<0.00003	*0.005*
Chromium (DIS)	<0.01	<0.01	*0.1*
Cobalt (DIS)	<0.01	<0.01	--
Copper (DIS)	<0.002	<0.002	*1.3*
Iron (DIS)	0.02	0.17	--
Lead (DIS)	0.0007	<0.0003	*0.015*
Manganese (DIS)	0.022	0.032	--
Mercury (DIS)	<0.000005	<0.000005	*0.002*
Molybdenum (DIS)	0.002	<0.002	--
Nickel (DIS)	0.001	<0.001	*0.1*
Selenium (DIS)	0.0004	<0.0002	*0.05*
Silver (DIS)	<0.02	<0.02	*0.1*
Strontium (DIS)	0.176	0.168	*4*
Thallium (DIS)	<0.0002	<0.0002	*0.002*
Uranium (DIS)	<0.008	<0.008	*0.03*
Zinc (DIS)	0.01	0.009	*2*

TABLE 10. FIELD WATER QUALITY PARAMETERS

Date	Temp (°C)	SC (µs/cm)	DO (mg/L)	pH (s.u.)	Temp (°C)	SC (µs/cm)	DO (mg/L)	pH (s.u.)	Temp (°C)	SC (µs/cm)	DO (mg/L)	pH (s.u.)	Temp (°C)	SC (µs/cm)	DO (mg/L)	pH (s.u.)	Temp (°C)	SC (µs/cm)	DO (mg/L)	pH (s.u.)	Temp (°C)	SC (µs/cm)	DO (mg/L)	pH (s.u.)
Site	SW-1T				SW-2T				SW-3T				SW-4T				SW-5T				SW-6T			
10/14/2016	6.49	426	10.53	8.05	5.87	430	11.21	8.12	5.54	431	11.08	8.15	6.09	413	10.57	7.62	2.46	412	11.75	6.97	4.8	440	10.98	6.67
10/28/2016	7.07	414	9.56	8.06	6.69	411	10.69	8.2	6.91	412	10.05	8.26	7.58	384	9.3	7.68	6.02	396	9.75	7.12	6	419	10.63	6.74
11/4/2016	6.74	406	10.17	8.13	2.85	411	12	8.14	0.94	412	12.2	8.26	1.77	391	11.76	7.55	-0.9	454	8.29	6.33	0.31	429	12.3	6.14
11/21/2016	-0.1	338	3	8.2	-0.2	383	6.3	8.2	-0.2	435	10.9	8.2	2.1	385	10.1	8.1	-0.2	447	9.6	7.7	3.51	418	10.54	7.78
12/6/2016	-1	108	4.3	6.9	-1	260	5.5	7.4	-1	230	19.8	7.7	-1	377	4.3	7.4	--	--	--	--	-1	430	12.44	7
12/19/2016	-1.1	403	9.4	7.7	-1	382	6.4	7.5	-0.9	285	3.93	7.3	-1	335	12.3	7.1	--	--	--	--	-0.4	420	13.6	6.9
1/10/2017	0.5	419	10.8	7.8	-0.2	423	11.2	7.7	--	--	--	--	-1	376	11.5	7.2	--	--	--	--	-0.03	429	10.9	7.1
1/25/2017	0	411	10.9	7.4	-0.5	414	11.2	7.6	--	--	--	--	-0.9	390	10.9	7.4	--	--	--	--	-0.2	418	12.9	6.3
2/10/2017	0.2	321	10.7	7.4	-0.3	323	11.4	7.4	-1	317	11	7.8	-1	300	10.8	7.1	--	--	--	--	0.5	386	11.1	5.2
3/3/2017	2.5	400	10.8	7.9	0.4	410	11.7	8.1	--	--	--	--	--	--	--	--	--	--	--	--	1.1	414	11	7.4
3/17/2017	0.8	177	12.4	7	-1	220	12.2	6.7	--	--	--	--	0.3	166	11.9	6.7	--	--	--	--	-0.6	266	12.3	4.9
3/31/2017	8.2	391	--	7.9	5.8	282	--	7.9	5.21	403	--	7.8	6.7	367	--	7.7	1.32	373	--	6.8	2.97	417	--	6.6
5/4/2017	16.4	385	8.1	8	14.6	390	9.3	8.2	14.3	393	9.04	8.3	--	--	--	--	8.1	400	9.5	7.7	7.1	408	10.5	7.8
5/22/2017	12.8	475	--	8.4	11	423	--	8.6	10.7	481	--	8.6	13.4	453	--	8.3	7.8	512	--	7.3	7.5	404	--	8.15
6/14/2017	7.8	374	9.3	8.1	7.6	385	9.4	8.2	7.2	375	9.8	8.3	6.6	376	9.1	8.1	6.2	3.8	8.6	7.9	5.3	410	8.8	7.5
7/12/2017	15.7	420	9.8	8.2	15.7	422	9.5	8.3	15.3	426	9.3	8.3	17.9	390	8.1	8.2	18.2	531	7.8	7.5	9.7	433	11.4	8
8/9/2017	15.8	420	7.3	8.3	16.3	420	7.9	8.4	14.7	415	7.6	8.5	18.1	400	6.5	8.2	--	--	--	--	10.1	424	9	7.2
9/6/2017	15	409	8.7	8.3	14.3	395	9.8	8.5	13	410	9.14	8.5	15.2	388	8.3	8	--	--	--	--	9.7	413	10.4	6.7
10/4/2017	6	423	9.6	8	2.4	399	10.6	8.3	0	371	11.1	8.3	1.6	360	10.2	7.9	--	--	--	--	1.7	416	10.8	7.9
Site	SW-7T				SW-8T				SW-9T				SW-10T				SW-14T							
10/14/2016	4.05	438	11.8	7.97	4.54	443	12.03	8.06	--	--	--	--	--	--	--	--	--	--	--	--				
10/28/2016	6.66	429	10.31	8.21	7.38	425	10.71	8.37	--	--	--	--	--	--	--	--	--	--	--	--				
11/4/2016	-0.79	450	12.92	7.95	-0.5	441	12.9	8.07	5.7	452	3.8	7.6	--	--	--	--	--	--	--	--				
11/21/2016	-0.1	433	12	8.3	-0.2	490	11.5	8.1	6.2	460	3.3	7.6	--	--	--	--	--	--	--	--				
12/6/2016	-1	430	7.5	7.7	--	--	--	--	5.3	450	2.8	8.1	--	--	--	--	--	--	--	--				
12/19/2016	-1	444	9.5	7.7	-1	259	3.3	7.2	5.1	448	4.1	7.9	--	--	--	--	--	--	--	--				
1/10/2017	--	--	--	--	--	--	--	--	4.9	467	4.2	7.9	--	--	--	--	--	--	--	--				
1/25/2017	--	--	--	--	--	--	--	--	4	455	4.7	7.6	--	--	--	--	--	--	--	--				
2/10/2017	--	--	--	--	--	--	--	--	4.1	408	5.1	7.2	3.11	406	9.1	7.9	3.22	406	12.2	7.9				
3/3/2017	--	--	--	--	-0.2	447	9.9	8	5.9	447	4.2	7.3	4.2	410	11.3	7.8	5.8	403	12	7.9				
3/17/2017	-1	142	12.4	7.1	-0.6	132	11.5	6.8	5.15	443	4.4	7	4.9	400	11	7.3	0.4	191	12	7.2				
3/31/2017	--	--	--	--	6.3	263	--	7.8	5.1	443	--	7.5	8.9	404	--	7.9	8	352	--	7.9				
5/4/2017	10.6	271	10.2	7.9	17.2	285	9.4	8.2	6.6	447	4.9	7.5	18	285	9.4	8.2	15.2	348	9.5	8				
5/22/2017	12.5	402	--	8.4	12	397	--	8.7	25	535	--	7	11.7	464	--	8.2	12.6	448	--	8.5				
6/14/2017	11.9	312	8.3	8.1	8.5	302	10	8.2	4.8	439	3.7	7.7	8.7	319	9.5	7.9	9.3	335	9.5	8				
7/12/2017	20.6	418	8.7	8.7	21	384	12.3	8.9	6.5	450	5.6	7.6	16.7	351	11.4	8.1	16.9	371	12	8.3				
8/9/2017	20.2	408	7	8.7	19.7	347	12.6	9.1	7	448	3.6	7.6	16.9	363	9	8.1	18.6	370	11.2	8.5				
9/6/2017	6.2	394	10.9	6.6	15.6	328	14.4	9.2	7.06	447	4.07	6.9	13	388	8.7	7.8	9	394	11.5	8.1				
10/4/2017	0.2	438	11.8	8.4	0.7	371	11.1	8.3	6.5	439	4	7.6	8.7	383	8.3	7.6	8.1	377	12	8.3				

4.0 ANALYSIS OF TRACER TESTING

4.1 ANALYSIS OF WATER LEVEL MOUNDING FROM INFILTRATION

The water-level observation data collected during and after infiltration were analyzed using AQTESOLV (v.4.5) to estimate aquifer properties near the top of the water table. The data were analyzed using Moench (1984) for simulating the infiltration into a trench by a large diameter well and using resultant observations of water-table rise (mounding) at nearby monitoring wells MW-14 and MW-15 (10 feet away). This method was used as the water discharged to the trench infiltrated in a small area within the trench and did not distribute evenly across the length of the trench. The hydraulic conductivity values estimated by the Moench solution were approximately 7.5 and 10 ft/day for sites near MW-14 and MW-15, respectively. Curve matches for the mounding analyses are included in Appendix C.

The mounding analysis shows that the bedrock near the water table is characterized by a higher hydraulic conductivity than the underlying bedrock. The transport of water discharged to the Eastern UIG will take place in the upper portion of the groundwater system. Therefore, the higher conductivity values are used to analyze the effects of discharge to the Eastern UIG. In addition, the mounding observed during the infiltration tests provide empirical data that there is a hydrologic connection between the infiltration trenches and the groundwater aquifer beneath the eastern UIG.

4.2 TRACER ANALYSIS

Although fluorescein or eosine was not detected in either MW-14 or MW-15, the mounding in the wells during the infiltration test show there is a direct connection from the infiltrated water to the top of the groundwater table beneath the Easter UIG. With a hydrologic connection established between the infiltrated water and groundwater system, it can be readily assumed that the dye added to the infiltration trench reached the groundwater table although it was not detected in either monitoring well. Some potential reasons that the dyes added to the infiltration trenches were not detected in the monitoring wells are as follows:

- The eosine and fluorescein tracers were transported in the upper portion of the aquifer where permeabilities are greater and did not reach the depth of the screen interval in each well;

- The dye was transported through a preferential flow path (e.g., fracture isolated from the wells) that was not in line with the monitoring wells; or
- The wells were not in line with the general flow direction of the dye infiltrated to the groundwater system.

4.2.1 Detectable Volume of Dye

The minimal volume of dye detectable at each monitoring site was estimated using a simple mixing analysis and making some conservative assumptions. The mixing analysis consisted of two parts: 1) Estimate the concentration of dye in the groundwater system, 2) Flow-based mixing calculation based on the estimated flow in the groundwater system(s) and flow in the stream. The assumptions used in the mixing analysis consisted of the following:

- Five percent of the dye is recovered in the carbon packets (discussed further below);
- The 5-gallon slug of dye mixes with 180 gallons of water infiltrating into the trench (30 minutes for dye to fully infiltrate with water being added to the trench at 6 gpm);
- Dye disperses through unsaturated zone and mixes over a 10 foot wide area (entered infiltration trench in 3 feet length of the trench and disperses to a 10 feet length at groundwater table);
- The discharge of the dye takes two times longer to discharge to the groundwater than it took to infiltrate into the infiltration trench (60 min) due to physical dispersion;
- Mixing of the dye with groundwater occurs within the first 15 feet of the aquifer;
- The carbon packets accumulate dye if present. Based on the packets being deployed for one week an accumulation factor (AF) of 311 was applied to the detection limit of the carbon packet (discussed further below); and
- Hydraulic conductivity of the groundwater system is 10 ft/day.

The assumption that 5% of the dye is recovered in the carbon packets is based on many possible factors that may limit the recovery of the dye. The limiting factors include potential attenuation of a portion of the dye in either the unsaturated zone and/or saturated bedrock, degradation from exposure to light, and contact of the carbon packet with dye within surface water. It is highly unlikely that the attenuation of the dye greatly reduced the dye available to discharge to surface water due to the high concentrations added to the infiltration trenches

(90,000 mg/L). Additionally, dye would discharge to surface water during both day and night, therefore, some dye would adsorb to the carbon packet prior to light degradation. The largest factor in limiting the recovery of dye is likely due to the carbon packets only being in contact with a portion of the water flowing in each stream and the remaining dye bypassing the packets. The carbon packets were placed in the portion of the stream with the greatest flow to increase the recovery potential of the carbon packets. The percent of dye in contact with the carbon packet is directly correlated with the size of the stream. The streams monitored in the tracer test are relatively small; therefore, a 5% recovery is a conservative assumption.

The carbon packets used for monitoring tracers adsorb dye and retain the dye as it transports through the carbon packet. This allows for continuous monitoring for fluorescein and eosine that were added to the infiltration trench. The adsorption and retention of the dye results in dye accumulating onto the activated carbon. Ozark Underground Laboratory (OUL) has conducted multiple tracer studies of which they have compared the concentration detected on the carbon packet to the concentration detected in the water sample collected from the same monitoring site to determine a representative accumulation factor (AF) (Aley, 2016). The AF is the ratio of the concentration in the elutant from the carbon packet extraction and the concentration detected in the water sample. The OUL study found that the median accumulation factor in the study was 311 for all of the samples analyzed in the study and ranged between 3 and 6,053 (Aley, 2016). The median accumulation factor was used to evaluate the detectable volume of dye.

The following mixing equations were used in conjunction with the assumptions above to determine the minimum detectable volume of dye at each monitoring station and monitoring event. First, the concentration of the dye in the bedrock beneath the infiltration trench was estimated based on the following equation:

Eq. 4-1:

$$\frac{C_{dye} * V_{dye} + C_{iw} * V_{iw} + C_{br} * V_{br}}{V_{dye} + V_{iw} + V_{br}} = C_{brm}$$

where:

C_{dye} concentration of the tracer added to infiltration trench

V_{dye} volume of dye added to infiltration trench

C_{iw} concentration of tracer in infiltrated water (10^{-3} x detection limit)

V_{iw} volume of infiltrated water mixed with tracer (6 gpm over 30 mins)

C_{br} concentration of tracer in upgradient bedrock (10^{-3} x detection limit)

V_{br} volume of upgradient groundwater (0.3 gpm over 60 mins)

C_{brm} resultant dye concentration in mixed bedrock groundwater

To determine the minimum detectable volume you must first establish a mixing equation for the transport of tracer in groundwater to mix with alluvial groundwater (if present) and surface water as follows:

Eq. 4-2:

$$\frac{C_{brm} * Q_{brm} + C_{qa} * Q_{qa} + C_{sw} * Q_{sw}}{Q_{brm} + Q_{qa} + Q_{sw}} = C_{rsw}$$

where:

C_{brm} concentration of dye in mixed bedrock groundwater

Q_{brm} flow rate of bedrock groundwater

C_{qa} concentration of tracer in alluvial groundwater (10^{-3} x detection limit)

Q_{qa} flow rate of alluvial groundwater (assume 100 gpm for Little Sheep Creek)

C_{sw} concentration of tracer in upgradient surface water (10^{-3} x detection limit)

V_{sw} Flow of surface water at monitoring station

C_{rsw} resultant dye concentration in stream after mixed

The detectable volume of each dye can be calculated by substituting equation 4-1 for C_{brm} in equation 4-2 and applying a recovery factor of 0.05 to the concentration of the dye added to the infiltration trench. Furthermore, substituting C_{rsw} with the detection limit (DL) of the elutant from the packet for each dye (Fluorescein – $2.5x10^{-5}$ mg/L and Eosine – $5.0x10^{-5}$

mg/L) divided by the AF (311). Lastly, rearranging the equation to solve for the volume of dye (V_{dye}) as follows:

Eq. 4-3:

$$V_{dye} = -\frac{(V_{inf} + V_{br})\left(C_{sw} * Q_{sw} + C_{qa} * Q_{qa} - \frac{DL}{AF}(Q_{br} + Q_{qa} + Q_{sw})\right) + C_{inf} * V_{inf} * Q_{br} + C_{br} * V_{br} * Q_{br}}{C_{sw} * Q_{sw} + C_{qa} * Q_{qa} + 0.05 * C_{dye} * Q_{br} - Q_{br} * DL - Q_{qa} * DL - Q_{sw} * DL}$$

The detectable volume of dye was calculated for based on the corresponding streamflow at each sample site throughout the tracer monitoring program. As noted above, the alluvial flow in the Little Sheep Creek was assumed to be 100 gpm. Brush Creek and the unnamed tributary to Little Sheep Creek have little to no alluvial material associated with them. Therefore, the flow for the alluvium was set to be 0.1 gpm for samples collected from sites on these streams. The detectable volume of fluorescein and eosine are summarized in Table 11. With the exception of the flow measured at SW-10T on 6/14/17, the calculated detectable volume of fluorescein ranged between 0.001 mL and 0.03 mL. The detection limit of eosine is two times more than fluorescein, therefore, the detectable volume for eosine ranged between 0.002 mL and 0.06 mL at the respective sites. Irrigation returns from the fields north of the county road resulted in the excessively high flow at SW-10T on 6/14/17 (Table 11). There were no other times when irrigation returns were observed to directly discharge to the gravel pit.

4.2.2 Tracer Travel Time

The estimated travel time for each tracer was estimated from the infiltration trench to each surface water body surrounding the Eastern UIG based on the Darcy's Flux equation ($V_{avg} = K*i/\eta_e$). The input assumptions and estimated average linear velocity are summarized in Table 12. Tracer travel times were calculated using the average linear velocities for each flow path (Table 13). The travel time for fluorescein, added to infiltration trench #1, to reach Brush Creek is estimated to be five to seven months, whereas it is estimated to take nine to twelve months to reach Little Sheep Creek. The estimated travel time (per the average linear velocity) for eosine to travel from Infiltration Trench #2 to the unnamed tributary is five to seven months and 21 to 28 months to reach Little Sheep Creek.

TABLE 11. DETECTABLE VOLUME OF TRACER

Station Name	Source Water	Date Collected	Flow (cfs)	Fluorescein (mL)	Eosine (mL)
SW-1T	Brush Creek	10/14/2016	0.04	<0.001	<0.002
SW-2T	Brush Creek	10/14/2016	0.1	<0.002	<0.004
SW-3T	Brush Creek	10/14/2016	0.11	<0.007	<0.013
SW-4T	Tributary to LSC	10/14/2016	0.02	<0.0004	<0.001
SW-6T	Little Sheep Creek	10/14/2016	0.16	<0.008	<0.015
SW-7T	Little Sheep Creek	10/14/2016	0.31	<0.011	<0.022
SW-8T	Little Sheep Creek	10/14/2016	0.34	<0.011	<0.022
SW-1T	Brush Creek	10/21/2016	0.03	<0.001	<0.001
SW-2T	Brush Creek	10/21/2016	0.11	<0.002	<0.004
SW-3T	Brush Creek	10/21/2016	0.11	<0.007	<0.013
SW-4T	Tributary to LSC	10/21/2016	0.01	<0.0002	<0.0004
SW-6T	Little Sheep Creek	10/21/2016	0.18	<0.006	<0.013
SW-7T	Little Sheep Creek	10/21/2016	0.08	<0.005	<0.009
SW-8T	Little Sheep Creek	10/21/2016	0.24	<0.007	<0.014
SW-1T	Brush Creek	10/28/2016	0.04	<0.001	<0.002
SW-2T	Brush Creek	10/28/2016	0.09	<0.002	<0.004
SW-3T	Brush Creek	10/28/2016	0.1	<0.006	<0.013
SW-4T	Tributary to LSC	10/28/2016	0.01	<0.0002	<0.0004
SW-6T	Little Sheep Creek	10/28/2016	0.14	<0.007	<0.014
SW-7T	Little Sheep Creek	10/28/2016	0.17	<0.008	<0.016
SW-8T	Little Sheep Creek	10/28/2016	0.24	<0.009	<0.018
SW-1T	Brush Creek	11/4/2016	0.03	<0.001	<0.001
SW-2T	Brush Creek	11/4/2016	0.08	<0.002	<0.003
SW-3T	Brush Creek	11/4/2016	0.04	<0.005	<0.010
SW-4T	Tributary to LSC	11/4/2016	0.01	<0.0002	<0.0004
SW-6T	Little Sheep Creek	11/4/2016	0.12	<0.007	<0.014
SW-7T	Little Sheep Creek	11/4/2016	0.1	<0.006	<0.013
SW-8T	Little Sheep Creek	11/4/2016	0.22	<0.009	<0.018
SW-6T	Little Sheep Creek	11/21/2016	0.17	<0.008	<0.016
SW-9T	Spring	11/21/2016	0.01	<0.0002	<0.0004
SW-14T	Little Sheep Creek	2/10/2017	0.31	<0.011	<0.022
SW-14T	Little Sheep Creek	3/3/2017	0.46	<0.014	<0.028
SW-1T	Brush Creek	3/31/2017	0.05	<0.001	<0.002
SW-2T	Brush Creek	3/31/2017	0.13	<0.003	<0.005
SW-4T	Tributary to LSC	3/31/2017	0.04	<0.001	<0.002
SW-6T	Little Sheep Creek	3/31/2017	0.27	<0.010	<0.020
SW-7T	Little Sheep Creek	3/31/2017	1.46	<0.033	<0.066
SW-8T	Little Sheep Creek	3/31/2017	0.94	<0.023	<0.046
SW-9T	Spring	3/31/2017	0.09	<0.002	<0.004
SW-10T	Gravel Pit Outfall	3/31/2017	0.14	<0.007	<0.014
SW-14T	Little Sheep Creek	3/31/2017	1.38	<0.032	<0.064
SW-1T	Brush Creek	4/17/2017	0.06	<0.001	<0.002
SW-2T	Brush Creek	4/17/2017	0.14	<0.003	<0.006
SW-3T	Brush Creek	4/17/2017	0.1	<0.006	<0.013

TABLE 11. DETECTABLE VOLUME OF TRACER

Station Name	Source Water	Date Collected	Flow (cfs)	Fluorescein (mL)	Eosine (mL)
SW-4T	Tributary to LSC	4/17/2017	0.01	<0.0002	<0.0004
SW-6T	Little Sheep Creek	4/17/2017	0.24	<0.009	<0.018
SW-7T	Little Sheep Creek	4/17/2017	1.16	<0.027	<0.054
SW-8T	Little Sheep Creek	4/17/2017	0.24	<0.009	<0.018
SW-9T	Spring	4/17/2017	0.05	<0.001	<0.002
SW-10T	Gravel Pit Outfall	4/17/2017	0.06	<0.006	<0.011
SW-14T	Little Sheep Creek	4/17/2017	1.26	<0.029	<0.058
SW-1T	Brush Creek	5/4/2017	0.09	<0.002	<0.004
SW-2T	Brush Creek	5/4/2017	0.19	<0.004	<0.008
SW-3T	Brush Creek	5/4/2017	0.11	<0.007	<0.013
SW-4T	Tributary to LSC	5/4/2017	0.03	<0.001	<0.001
SW-6T	Little Sheep Creek	5/4/2017	0.34	<0.011	<0.022
SW-7T	Little Sheep Creek	5/4/2017	0.58	<0.016	<0.032
SW-8T	Little Sheep Creek	5/4/2017	0.42	<0.013	<0.026
SW-9T	Spring	5/4/2017	0.06	<0.001	<0.002
SW-10T	Gravel Pit Outfall	5/4/2017	0.07	<0.006	<0.012
SW-14T	Little Sheep Creek	5/4/2017	1.38	<0.032	<0.064
SW-1T	Brush Creek	5/22/2017	0.12	<0.002	<0.005
SW-2T	Brush Creek	5/22/2017	0.17	<0.003	<0.007
SW-3T	Brush Creek	5/22/2017	0.14	<0.007	<0.014
SW-4T	Tributary to LSC	5/22/2017	0.03	<0.001	<0.001
SW-6T	Little Sheep Creek	5/22/2017	0.32	<0.011	<0.022
SW-7T	Little Sheep Creek	5/22/2017	0.45	<0.013	<0.026
SW-8T	Little Sheep Creek	5/22/2017	0.44	<0.013	<0.026
SW-9T	Spring	5/22/2017	0.06	<0.001	<0.002
SW-10T	Gravel Pit Outfall	5/22/2017	0.16	<0.008	<0.015
SW-14T	Little Sheep Creek	5/22/2017	1.38	<0.032	<0.064
SW-1T	Brush Creek	6/14/2017	0.19	<0.004	<0.008
SW-2T	Brush Creek	6/14/2017	0.27	<0.005	<0.011
SW-3T	Brush Creek	6/14/2017	0.28	<0.010	<0.020
SW-4T	Tributary to LSC	6/14/2017	0.03	<0.001	<0.001
SW-6T	Little Sheep Creek	6/14/2017	0.51	<0.015	<0.030
SW-8T	Little Sheep Creek	6/14/2017	0.66	<0.017	<0.034
SW-9T	Spring	6/14/2017	0.04	<0.001	<0.002
SW-10T	Gravel Pit Outfall	6/14/2017	7.73*	<0.158	<0.316
SW-1T	Brush Creek	7/12/2017	0.09	<0.002	<0.004
SW-2T	Brush Creek	7/12/2017	0.12	<0.002	<0.005
SW-3T	Brush Creek	7/12/2017	0.09	<0.006	<0.012
SW-4T	Tributary to LSC	7/12/2017	0.01	<0.0002	<0.0004
SW-6T	Little Sheep Creek	7/12/2017	0.25	<0.009	<0.019
SW-7T	Little Sheep Creek	7/12/2017	0.17	<0.006	<0.012
SW-8T	Little Sheep Creek	7/12/2017	0.2	<0.008	<0.017
SW-9T	Spring	7/12/2017	0.03	<0.001	<0.001
SW-10T	Gravel Pit Outfall	7/12/2017	0.5	<0.014	<0.028

TABLE 11. DETECTABLE VOLUME OF TRACER

Station Name	Source Water	Date Collected	Flow (cfs)	Fluorescein (mL)	Eosine (mL)
SW-1T	Brush Creek	8/9/2017	0.04	<0.001	<0.002
SW-2T	Brush Creek	8/9/2017	0.07	<0.001	<0.003
SW-3T	Brush Creek	8/9/2017	0.06	<0.006	<0.011
SW-4T	Tributary to LSC	8/9/2017	0.008	<0.002	<0.003
SW-6T	Little Sheep Creek	8/9/2017	0.21	<0.009	<0.017
SW-7T	Little Sheep Creek	8/9/2017	0.11	<0.007	<0.013
SW-8T	Little Sheep Creek	8/9/2017	0.1	<0.006	<0.013
SW-9T	Spring	8/9/2017	0.01	<0.0002	<0.0004
SW-10T	Gravel Pit Outfall	8/9/2017	0.21	<0.009	<0.017
SW-14T	Little Sheep Creek	8/9/2017	0.74	<0.019	<0.038
SW-1T	Brush Creek	9/6/2017	0.03	<0.001	<0.001
SW-2T	Brush Creek	9/6/2017	0.06	<0.006	<0.011
SW-3T	Brush Creek	9/6/2017	0.06	<0.006	<0.011
SW-4T	Tributary to LSC	9/6/2017	0.006	<0.0001	<0.000
SW-6T	Little Sheep Creek	9/6/2017	0.15	<0.007	<0.015
SW-7T	Little Sheep Creek	9/7/2017	0.05	<0.005	<0.011
SW-8T	Little Sheep Creek	9/6/2017	0.04	<0.005	<0.010
SW-9T	Spring	9/6/2017	0.01	<0.0002	<0.0004
SW-14T	Little Sheep Creek	9/7/2017	0.59	<0.016	<0.032

* Flow measurement at SW-10T on 6/14/17 was impacted by flood irrigation input from hay fields to the north.

TABLE 12. SUMMARY OF DARCY FLUX CALCULATIONS

Flow Paths	Hydraulic Conductivity (ft/day)	Porosity	Gradient	Velocity (ft/day)
Inf. #1 to Brush Creek	7.5 - 10	0.1	0.06	4.5 - 6
Inf. #1 to Alluvium	7.5 - 10	0.1	0.04	3 - 4
Inf. #2 to Unnamed Tributary	7.5 - 10	0.1	0.04	4.5 - 6
Inf. #2 to Alluvium	7.5 - 10	0.1	0.04	3 - 4
Alluvium to Little Sheep Creek	100	0.25	0.03	12

TABLE 13. ESTIMATED TRAVEL TIMES OF DYE TRACERS

Flow Paths	Distance (feet)	Travel Time (months)
Inf. Trench #1 to Brush Creek	900	5-7
Inf. Trench #2 to Unnamed Tributary	1000	6-7
Inf. Trench #1 to Alluvium to Little Sheep Creek	1000 + 300	9-12
Inf. #2 to Alluvium to Little Sheep Creek	2400 + 300	21-28

The estimated travel times provide a metric to evaluate if the tracer has reached the monitored surface water bodies. However, the transport of tracers can be affected by longitudinal dispersion and the effects of differential velocities associated with fracture media. Groundwater beneath the infiltration trenches is in fractured shales where flow occurs within fractures (typically bedding plane fractures) within the bedrock. Groundwater velocities in discrete factures are typically much higher compared to velocities in porous media (Singhal and Gupta, 2010). In addition, the tracers will be affected by hydrodynamic dispersion, which will cause the tracer to reach greater distances than just by advection (average linear velocity). Based on the estimated travel times and understanding that the transport of solutes in fracture flow is much faster than porous media, it is likely that the tracer has transported to within or further than the monitored surface water bodies.

5.0 SUMMARY OF RESULTS

The hydrogeologic investigation at the eastern UIG provides some essential information for evaluating the groundwater response to infiltration. The aquifer was characterized through well drilling, aquifer tests, and water level responses to infiltration. The connection between the groundwater system beneath the Eastern UIG and surrounding surface water bodies has been characterized through the introduction tracers and eleven months of continuous tracer monitoring. Below are the key findings from the eastern UIG hydrologic investigation:

- The hydraulic conductivity of the upper portion of the groundwater aquifer ranges between 7.5 and 10 ft/day.
- There is a decrease in permeability with depth as seen in the lower hydraulic conductivities (0.25 and 0.33 ft/day) from the slug tests at MW-14 and MW-15 (completed about 19 to 32 feet below the water table).
- The mounding observed in the groundwater system provided empirical evidence that there is a hydrologic connection between the proposed infiltration gallery and the groundwater system beneath the eastern UIG.
- With a hydrologic connection between the infiltration trenches and groundwater system it is reasonable to assume the tracers mixed with the groundwater system beneath the infiltration trenches.
- Using conservative assumptions for groundwater mixing and tracer recovery the tracer monitoring would have been able to detect if a minute volume of the tracer would have discharged to the surface water bodies (0.001 to 0.03 mL).
- Estimated travel times based on Darcy's Flux (very conservative for fracture bedrock) indicate fluorescein would have reached Brush Creek in five to seven months and Little Sheep Creek in nine to twelve months. Eosine would have reached the unnamed tributary in six to seven months and will reach Little Sheep Creek in 21 to 28 months.
- The estimated travel times are likely to be much shorter due to the groundwater beneath the UIG being in a fracture flow bedrock system.

The established hydrologic connection between the infiltration trenches and the groundwater system and lack of detection of even very minute volumes of dye at any surface water monitoring site is evidence that the groundwater system beneath the eastern UIG is not in direct connection with the monitored surface water bodies. Tintina plans to continue the tracer monitoring through 2017 and possibly beyond to provide further data on the connection between groundwater beneath the eastern UIG and surrounding surface water bodies.

6.0 REFERENCES

Aley, T. 2016. Using activated carbon samplers to improve detection of fluorescent tracer dyes in groundwater remediation studies, Tenth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Palm Springs, CA. ISBN 978-0-9964071-1-3, Battelle Memorial Institute. Paper A-056 10p.

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Moench, A.F., 1984. Double-porosity models for a fissured groundwater reservoir with fracture skin, Water Resources Research, vol. 20, no. 7, pp. 831-846.

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APPENDIX A

WELL LOGS

Hydrometrics, Inc.

Consulting Scientists and Engineers
Helena, Montana

Monitor Well Log

Hole Name: MW-14

Date Hole Started: 9/15/2016 Date Hole Finished: 9/15/2016

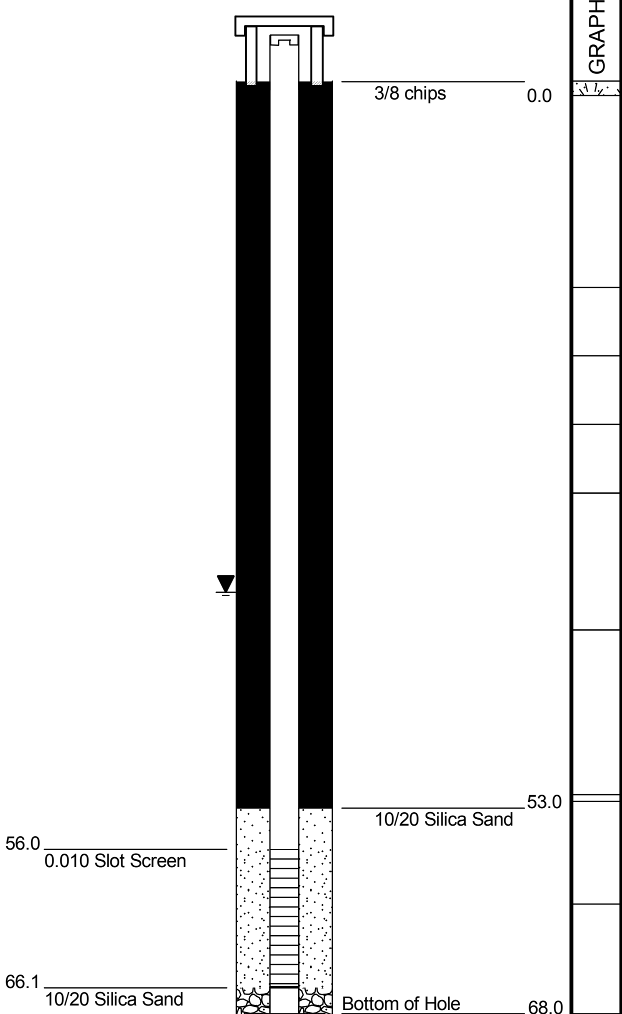
Client: Tintina Resources
Project: Black Butte Copper Project
County: Meagher State: MT
Property Owner: Holmstrom Short Ranch LLC
Legal Description: SW,SE, S30, T12N, R07E
Location Description: Eastern UIG
Recorded By: J. Harwood
Drilling Company: O'Keefe Drilling
Driller: Scott/Corey
Drilling Method: DR
Drilling Fluids Used: Air
Purpose of Hole: Install Monitor Well
Target Aquifer: First Water
Hole Diameter (in): 6
Total Depth Drilled (ft): 68

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	2-inch, flush threaded, Sch 40, PVC	+2.7 to 66
Surface Casing Used?	Y	6-inch steel	+2.8 to 36
Screen/Perforations?	Y	0.010-inch slot, Sch 40, PVC	56 to 66
Sand Pack?	Y	10/20 Silica Sand	53 to 68
Annular Seal?	Y	Bentonite Chips	0 to 53
Surface Seal?	Y	Cement	0 - 6"
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Air for 1 hour and pumped 3 bore volumes	
Water Samples Taken?	Y	Commons, Nutrients, Metals	
Boring Samples Taken?	Y	chips	Every 5 feet

Northing: 5179376.766 Easting: 508255.625
Static Water Level Below MP: 39.94 Surface Casing Height (ft): 2.8
Date: 9/19/16 Riser Height (ft): 2.7
MP Description: Top of PVC Ground Surface Elevation (ft): 5761.16
MP Height Above or Below Ground (ft): 2.7 MP Elevation (ft): 5763.873

Remarks: Water was encountered below fractured zone (at 52 feet) at 56 feet bgs. Fifteen minute break yielded 5 gallons drilled to 68 feet.

WELL CONSTRUCTION



GEOLOGICAL DESCRIPTION

0.0 - 1.0' **TOPSOIL**
Dark brown, sand and silt topsoil with angular-subrounded clasts weathered shale clasts. Dry.

1.0 - 15.0' **SILTY SOIL**
Buff tan colored silt with moderately weathered shale clasts. Shale is orange-tan to brown, mottled black to tan, very thinly laminated with very thin black veins and dendrites (pyrite?), shale is weathered along veins. Clasts have iron oxide fractured surfaces with black dendritics, reacts with HCl. Dry.

15.0 - 20.0' **SILT/SHALE**
Gray brown silt with angular weak to moderately weathered shale clasts; dark gray to buff tan with iron oxidized fracture surfaces, weak to moderate reaction to HCl. Dry.

20.0 - 25.0' **SHALE**
Thinly bedded, weakly weathered black shale; black to buff-tan. Some iron surfaces and clacite vein fill; up to 4 mm. Alteration is peripheral to fractures only, weak reaction to HCl. Dry.

25.0 - 30.0' **SHALE**
Thinly bedded dark gray to black shale as above. Weak reaction to HCl.

At 28 feet, less weathering, chips were very angular, small (less than 1/4"), seems to be more competent shale. Dry

30.0 - 40.0' **SHALE**
Hard black shale, not weathered, occasional iron oxide fracture surfaces, very thin calcite veins.

At 39 - 39.5 feet, weak to moderate weathered black shale; tan-brown to black, includes iron fractured surfaces, very thin calcite veins . Rock mass does not react with HCl. Cuttings returned with fine silt and had silty clay coating.

40.0 - 52.0' **SHALE**
Non-weathered, thinly bedded black shale with very thin calcite veins. Hard, slower drilling, small, less than 1/4" chip return.

52.0 - 52.5' **SHALE**
Gray-brown silt with weakly oxidized black shale as above, orange-yellow iron oxide on fracture surfaces.

55.0 - 60.0' **SHALE**
Thinly bedded black shale with abundant fines, soft drilling, very dusty, thin calcite veins.

At 56 feet, one foot into new rod, entered first water, produced approximately 4 gallons until dry. Wet

60.0 - 68.0' **SHALE**
Very black thinly laminated black shale, abundant fines - silty calcite veins up to 1 cm, shale is calcareous. Wet to damp.

Hydrometrics, Inc.

Consulting Scientists and Engineers
Helena, Montana

Monitor Well Log

Hole Name: MW-15

Date Hole Started: 9/16/2016 Date Hole Finished: 9/16/2016

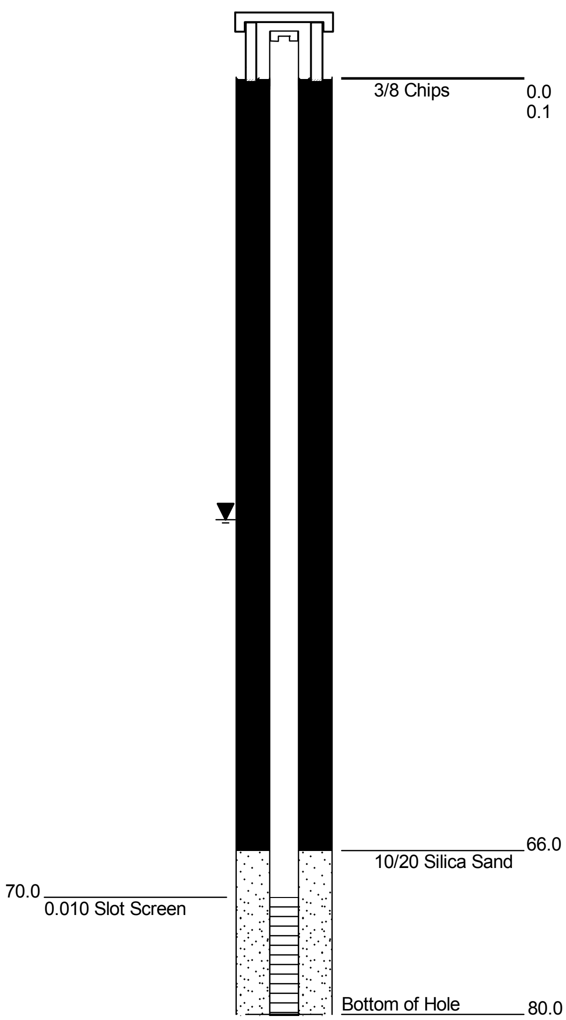
Client: Tintina Resources
Project: Black Butte Copper Project
County: Meagher State: MT
Property Owner: Holmstrom Short Ranch LLC
Legal Description: NW, NE, S31, T12N, R07E
Location Description: Eastern UIG
Recorded By: J. Harwood
Drilling Company: O'Keefe Drilling
Driller: Scott/Corey
Drilling Method: DR
Drilling Fluids Used: Air
Purpose of Hole: Install Monitor Well
Target Aquifer: First Water
Hole Diameter (in): 6"
Total Depth Drilled (ft): 80

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	2-inch, flush threaded, Sch 40, PVC	+2.1 to 80
Surface Casing Used?	Y	6-inch steel	+2.3 to 5
Screen/Perforations?	Y	0.010-inch slot, Sch 40, PVC	70 to 80
Sand Pack?	Y	10/20 Silica Sand	66 to 80
Annular Seal?	Y	Bentonite Chips	0 to 66
Surface Seal?	Y	Cement	0 to 6"
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Air for 1 hour and pumped 3 bore volumes	
Water Samples Taken?	Y	Commons, Nutrients, Metals	
Boring Samples Taken?	Y	chips	Every 5 feet

Northing: 5179071.066 Easting: 508290.888
Static Water Level Below MP: 39.85 Surface Casing Height (ft): 2.3
Date: 9/19/16 Riser Height (ft): 2.1
MP Description: Top of PVC Ground Surface Elevation (ft): 5795.26
MP Height Above or Below Ground (ft): 2.1 MP Elevation (ft): 5797.341

Remarks: Water was encountered at 68 feet.

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 1.0' **TOPSOIL**
Dark brown, sand and silt topsoil with angular-subrounded weathered shale clasts, dry.

1.0 - 3.0' **SHALE**
Orange-brown, highly weathered shale and buff tan silt, dry.

3.0 - 5.0' **SHALE**
Buff tan, weathered shale and silty fines, dusty, occasional red-brown fines, dry.

5.0 - 12.0' **SILT/SHALE**
Increased red-brown silt with brown-gray oxidized, silty shale, weakly reaction to HCl, dry.

12.0 - 20.0' **SHALE**
Thinly laminated, weak to moderate oxidation, orange-brown to black shale, with very thin calcite veins, occasional thick calcite vein fill chip, fractured surfaces are weak to moderately oxidized, occasional laminations are red-orange oxidation, dry.

At 17 - 20 feet, Less weathering, decreased silty fines, more competent shales, approximately 40% of return are chips.

20.0 - 35.0' **SHALE**
Weakly weathered black shale with tan-gray silty fines, angular to subangular chips, large fragments up to 3/4 inch. Medium gray to black thinly lam shale, fractured surfaces have common red-orange oxidation. Weak reaction to HCl. Dry.

35.0 - 48.0' **SHALE**
Weak to no weathering, no silty fines, competent shale, slower drilling, fine to coarse angular chips; thinly laminated, dark gray to black, weakly reactive to HCl. Dry.

48.0 - 62.0' **SHALE**
Fractured shale, abundant black powdery fines, soft drilling. Thinly to thick laminated dark gray to black shale, no oxidation, not reactive to HCl, minor very thin calcite veins. Dry.

62.0 - 70.0' **SHALE**
Dark gray shale to light gray shale is very thinly to thickly laminated, weak reaction to HCl. Dry.

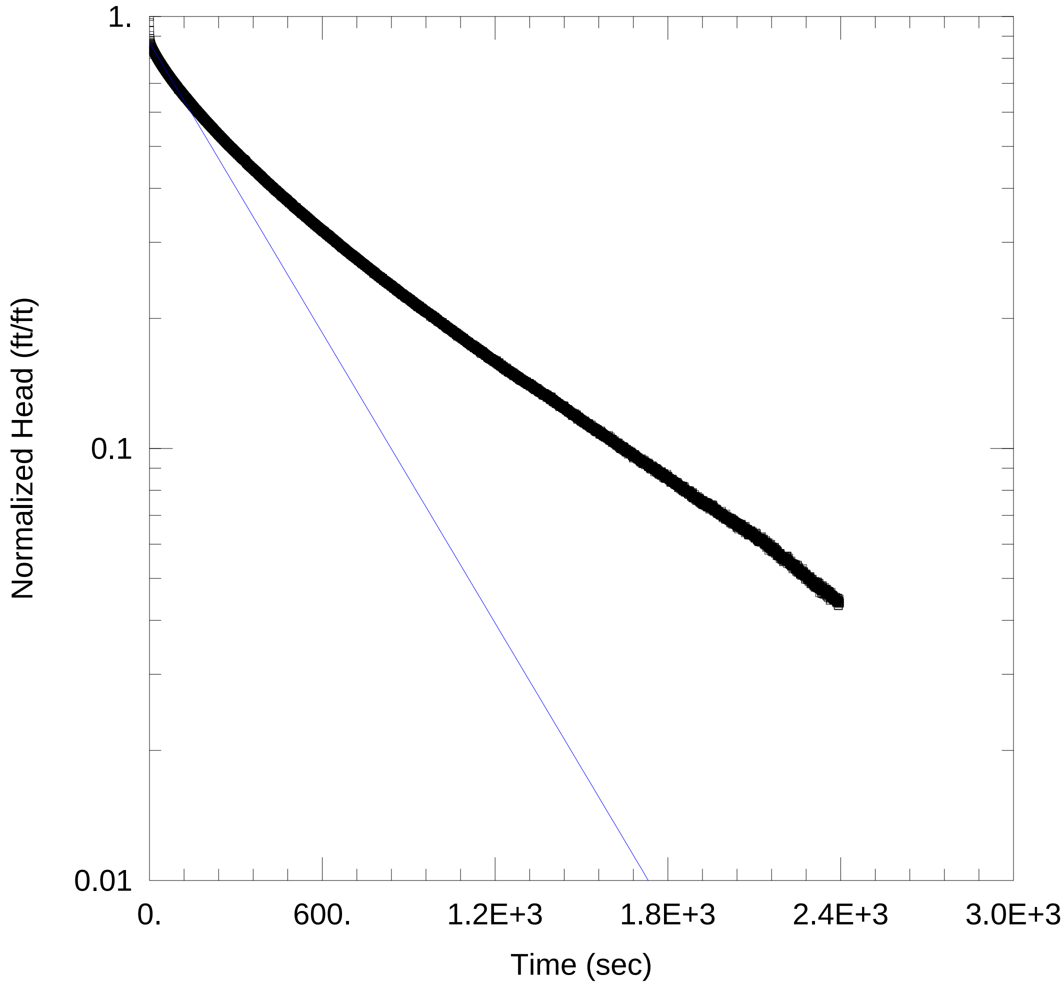
at 64 feet, dusty, abundant silty-powdery fines with coarse chips, possible shear zone.

at 68 feet, encountered water upon re-entry with additional drilling rod. Wet.

70.0 - 80.0' **SHALE**
Abundant fines, powdery, very dusty, only approximately 10 to 15% small chips, less than 1 cm, weekly reactive to HCl. Ten feet of water at 80 feet at the time of drilling.

APPENDIX B

SLUG TEST ANALYSES



WELL TEST ANALYSIS

Data Set: K:\project\11048\GW\2017 Slug Tests\MW_14_15_170126\MW_14Slug1BouwerRice.aqt
Date: 03/08/17 Time: 11:08:09

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Tintina Resources
Location: Black Butte
Test Well: MW-14
Test Date: 01/26/2017

AQUIFER DATA

Saturated Thickness: 15. ft Anisotropy Ratio (Kz/Kr): 1.

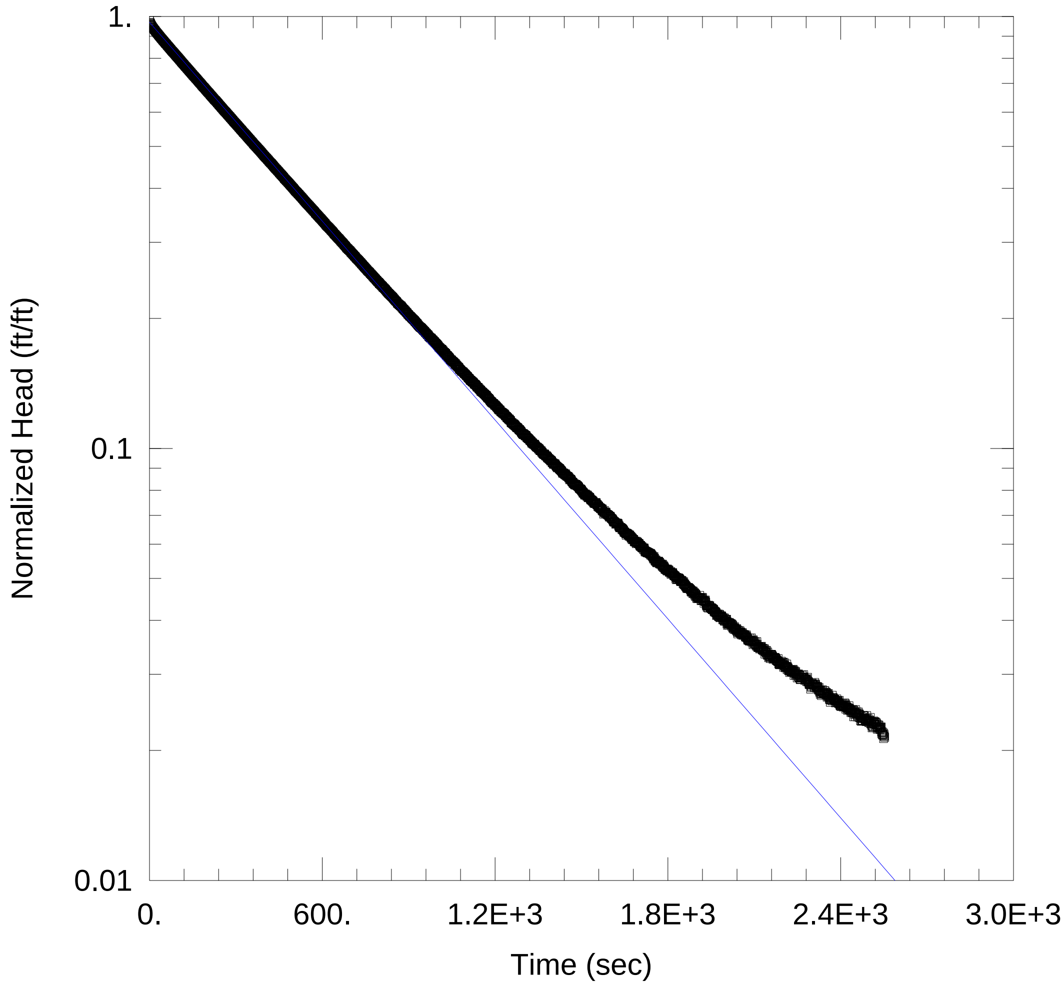
WELL DATA (MW-14)

Initial Displacement: 1.777 ft Static Water Column Height: 0. ft
Total Well Penetration Depth: 26. ft Screen Length: 10. ft
Casing Radius: 0.083 ft Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.33 ft/day y0 = 1.545 ft



WELL TEST ANALYSIS

Data Set: K:\project\11048\GW\2017 Slug Tests\MW_14_15_170126\MW_15_Slug1BouwerRice.aqt
Date: 03/08/17 Time: 11:07:21

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Tintina Resources
Location: Black Butte
Test Well: MW-15
Test Date: 01/26/2017

AQUIFER DATA

Saturated Thickness: 15. ft
Anisotropy Ratio (Kz/Kr): 1.

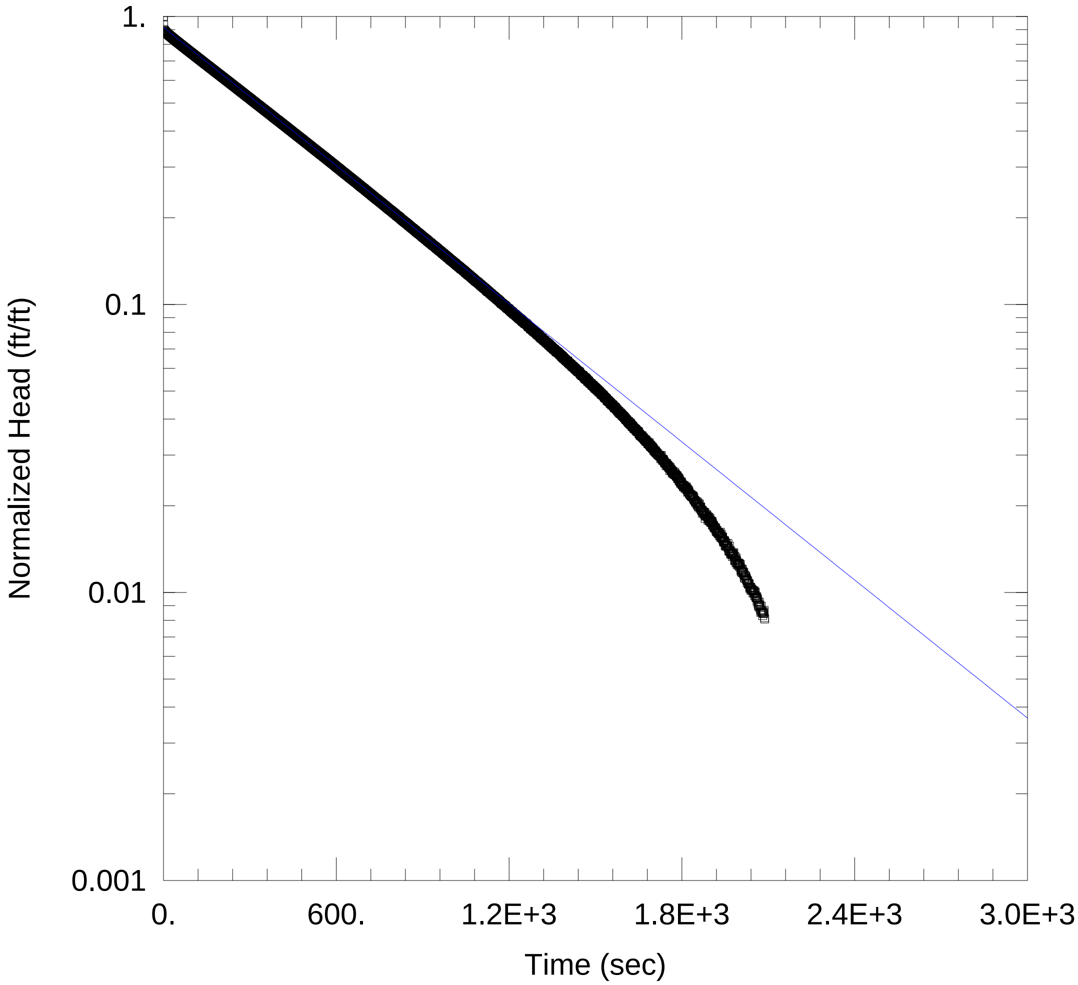
WELL DATA (MW-15)

Initial Displacement: 3.934 ft
Total Well Penetration Depth: 40. ft
Casing Radius: 0.083 ft
Static Water Column Height: 0. ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.24 ft/day
y0 = 3.815 ft



WELL TEST ANALYSIS

Data Set: K:\project\11048\GW\2017 Slug Tests\MW_14_15_170126\MW_15Slug2BouwerRice.aqt
Date: 03/08/17 Time: 11:10:27

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Tintina Resources
Location: Black Butte
Test Well: MW-15
Test Date: 01/26/2017

AQUIFER DATA

Saturated Thickness: 15. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW-15)

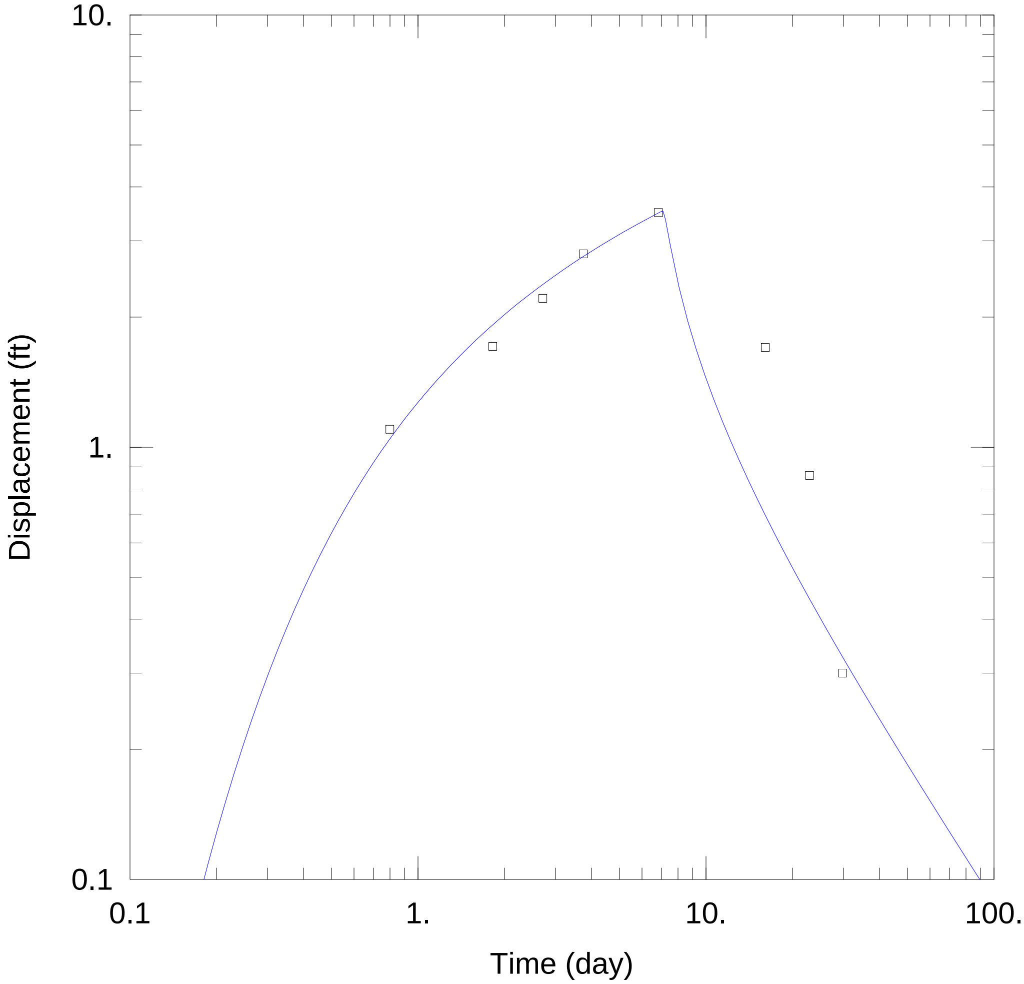
Initial Displacement: 4.95 ft
Total Well Penetration Depth: 40. ft
Casing Radius: 0.083 ft
Static Water Column Height: 0. ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.25 ft/day
y0 = 4.533 ft

APPENDIX C

MOUNDING ANALYSIS



WELL TEST ANALYSIS

Data Set: K:\...\MW_14 Trench_Moenchslab.aqt
Date: 03/08/17 Time: 14:52:39

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Tintina Resources
Location: Black Butte
Test Well: MW-14
Test Date: 10/4/16

AQUIFER DATA

Saturated Thickness: 10. ft Slab Block Thickness: 2. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Trench	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-14	10	0

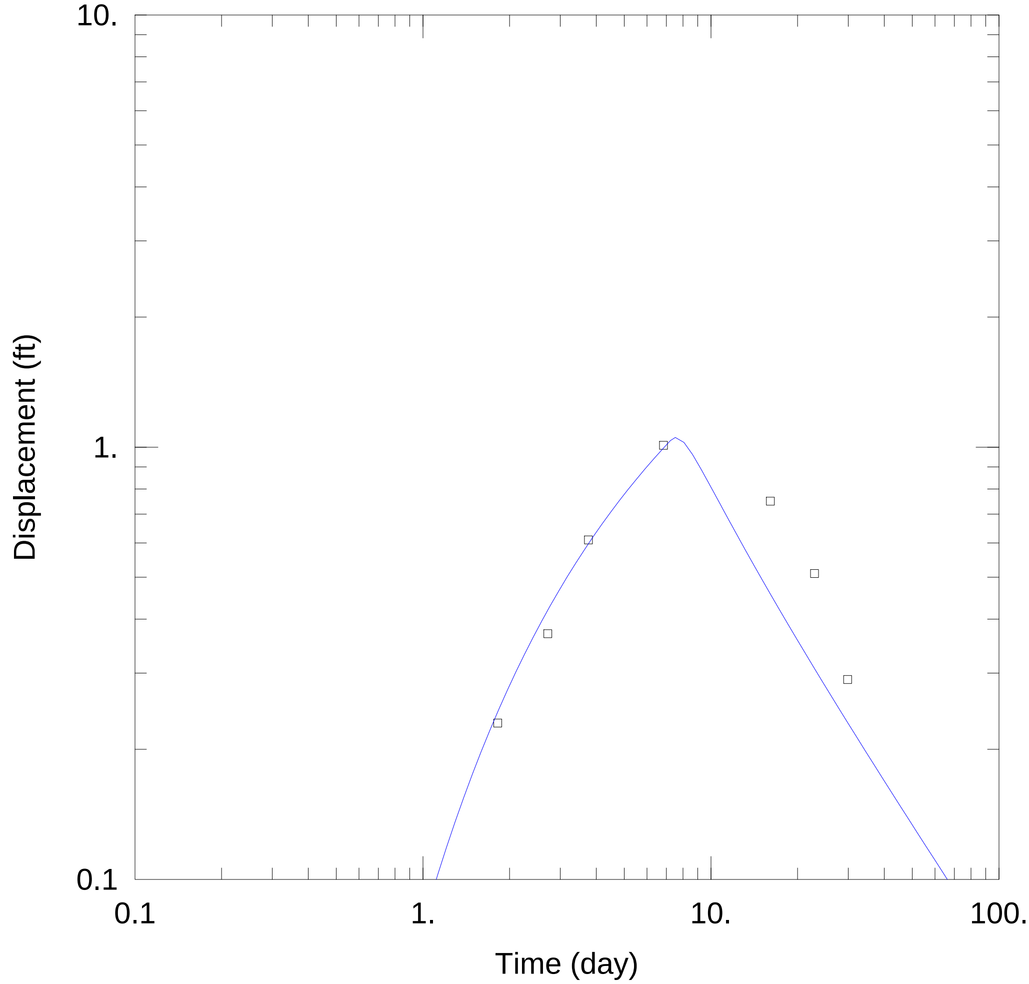
SOLUTION

Aquifer Model: Fractured

Solution Method: Moench w/slab blocks

K = 7.5 ft/day
K' = 1.122E-10 ft/day
Sw = 0.15
r(w) = 0.5 ft

Ss = 0.06797 ft^{-1}
Ss' = 1.995E-10 ft^{-1}
Sf = 0.4
r(c) = 2. ft



WELL TEST ANALYSIS

Data Set: K:\...\MW_15 Trench_Moenchslab.aqt
Date: 03/08/17 Time: 14:54:19

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Tintina Resources
Location: Black Butte
Test Well: MW-15
Test Date: 10/4/16

AQUIFER DATA

Saturated Thickness: 10. ft Slab Block Thickness: 2. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Trench	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-15	10	0

SOLUTION

Aquifer Model: Fractured Solution Method: Moench w/slab blocks

K = 10. ft/day
K' = 1.585E-7 ft/day
Sw = 0.15
r(w) = 0.5 ft

Ss = 0.6542 ft^{-1}
Ss' = 0.001 ft^{-1}
Sf = 0.4
r(c) = 0.5 ft

APPENDIX D

LABORATORY TRACER RESULTS

OUL Number	Station Number	Station Name	Date/Time Placed	Date/Time Collected	Fluorescein		Eosine		Rhodamine WT	
					Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)
B8229	1	SW-1T	9/14/16 1255	9/29/16 1320	521.8*	0.445	543.6*	0.782	ND	
B8229D	1	SW-1T	9/14/16 1255	9/29/16 1320	ND		ND		ND	
B8230	2	SW-2T	9/14/16 1225	9/29/16 1245	ND		ND		ND	
B8231	3	SW-3T	9/14/16 1215	9/29/16 1225	ND		ND		ND	
B8232	4	SW-4T	9/14/16 1120	9/28/16 1245	ND		ND		ND	
B8233	5	SW-5T	9/14/16 1055	9/28/16 1315	ND		ND		ND	
B8234	6	SW-6T	9/14/16 1045	9/29/16 1130	ND		ND		ND	
B8235	7	SW-7T	9/14/16 1145	9/29/16 1155	ND		ND		ND	
B8236	8	SW-8T	9/14/16 1205	9/29/16 1210	ND		ND		ND	
B8237	9	MW-14	9/22/16 NT	9/28/16 1200	ND		ND		ND	
B8238	10	MW-15	9/22/16 NT	9/28/16 1130	ND		ND		ND	
B8406	1	SW-1T	9/29/16 1320	10/14/16 1310	ND		ND		ND	
B8407	2	SW-2T	9/29/16 1245	10/14/16 1243	ND		ND		ND	
B8408	3	SW-3T	9/29/16 1225	10/14/16 1223	ND		ND		ND	
B8409	4	SW-4T	9/28/16 1245	10/14/16 1110	ND		ND		ND	
B8410	5	SW-5T	9/28/16 1315	10/14/16 1020	ND		ND		ND	
B8411	6	SW-6T	9/29/16 1130	10/14/16 0955	ND		ND		ND	
B8412	7	SW-7T	9/29/16 1155	10/14/16 1135	ND		ND		ND	
B8413	8	SW-8T	9/29/16 1210	10/14/16 1203	ND		ND		ND	
B8414	9	MW-14	9/28/16 1200	10/12/16 1252	ND		ND		ND	
B8415	10	MW-15	9/28/16 1130	10/12/16 1155	ND		ND		ND	
B8556	1	SW-1T	10/14/16 1315	10/21/16 1415	ND		ND		ND	
B8557	2	SW-2T	10/14/16 1246	10/21/16 1350	ND		ND		ND	
B8558	3	SW-3T	10/14/16 1230	10/21/16 1330	ND		ND		ND	
B8559	4	SW-4T	10/14/16 1110	10/21/16 1615	ND		ND		ND	
B8560	Laboratory control charcoal blank									
B8561	5	SW-5T	10/14/16 1020	10/21/16 1540	ND		ND		ND	
B8562	6	SW-6T	10/14/16 0955	10/21/16 1520	ND		ND		ND	
B8563	7	SW-7T	10/14/16 1150	10/21/16 1450	ND		ND		ND	
B8564	8	SW-8T	10/14/16 1217	10/21/16 1310	ND		ND		ND	
B8565	9	MW-14	10/12/16 1302	10/21/16 1900	ND		ND		ND	
B8566	10	MW-15	10/12/16 1230	10/21/16 1730	ND		ND		ND	
B8672	9	MW-14	10/12/16 1252	10/21/16 1900	ND		ND		ND	
B8673	10	MW-15	10/12/16 1155	10/21/16 1730	ND		ND		ND	
B8662	1	SW-1T	10/21/16 1425	10/28/16 1615	ND		ND		ND	
B8663	2	SW-2T	10/21/16 1400	10/28/16 1545	ND		ND		ND	

OUL Number	Station Number	Station Name	Date/Time Placed	Date/Time Collected	Fluorescein		Eosine		Rhodamine WT	
					Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)
B8664	3	SW-3T	10/21/16 1340	10/28/16 1520	ND		ND		ND	
B8665	4	SW-4T	10/21/16 1625	10/28/16 1345	ND		ND		ND	
B8666	5	SW-5T	10/21/16 1545	10/28/16 1245	ND		ND		ND	
B8667	6	SW-6T	10/21/16 1530	10/28/16 1218	ND		ND		ND	
B8668	7	SW-7T	10/21/16 1500	10/28/16 1435	ND		ND		ND	
B8669	8	SW-8T	10/21/16 1320	10/28/16 1505	ND		ND		ND	
B8670	9	MW-14	10/21/16 1905	10/28/16 1400	ND		ND		ND	
B8671	10	MW-15	10/21/16 1735	10/28/16 1310	ND		ND		ND	
B8702	1	SW-1T	10/28/16 1615	11/4/16 1350	ND		ND		ND	
B8703	2	SW-2T	10/28/16 1545	11/4/16 1330	ND		ND		ND	
B8704	3	SW-3T	10/28/16 1520	11/4/16 1305	ND		ND		ND	
B8705	4	SW-4T	10/28/16 1345	11/4/16 1120	ND		ND		ND	
B8706	5	SW-5T	10/28/16 1245	11/4/16 1035	ND		ND		ND	
B8707	6	SW-6T	10/28/16 1218	11/4/16 1020	ND		ND		ND	
B8708	7	SW-7T	10/28/16 1435	11/4/16 1230	ND		ND		ND	
B8709	8	SW-8T	10/28/16 1505	11/4/16 1250	ND		ND		ND	
B8778	9	MW-14	10/28/16 1400	11/4/16 1140	ND		ND		ND	
B8710	10	MW-15	10/28/16 1310	11/4/16 1105	ND		ND		ND	
B8949	1	SW-1T	11/4/16 1350	11/22/16 0905	ND		ND		ND	
B8950	2	SW-2T	11/4/16 1330	11/22/16 0835	ND		ND		ND	
B8951	3	SW-3T	11/4/16 1305	11/22/16 0810	ND		ND		ND	
B8952	4	SW-4T	11/4/16 1120	11/21/16 1625	ND		ND		ND	
B8953	5	SW-5T	11/4/16 1035	11/21/16 1520	ND		ND		ND	
B8954	6	SW-6T	11/4/16 1020	11/21/16 1450	ND		ND		ND	
B8955	7	SW-7T	11/4/16 1230	11/21/16 1555	ND		ND		ND	
B8956	8	SW-8T	11/4/16 1250	11/22/16 0745	ND		ND		ND	
B8957	9	SW-9T	11/4/16 1205	11/21/16 1540	ND		ND		ND	
B8958	10	MW-14	11/4/16 1140	11/21/16 1650	ND		ND		ND	
B8959	11	MW-15	11/4/16 1105	11/22/16 0950	ND		ND		ND	
B8960	Laboratory control charcoal blank									
B9076	1	SW-1T	11/22/16 0905	12/6/16 1330	ND		ND		ND	
B9077	2	SW-2T	11/22/16 0835	12/6/16 1310	ND		ND		ND	
B9078	3	SW-3T	11/22/16 0810	12/6/16 1250	ND		ND		ND	
B9079	4	SW-4T	11/21/16 1045	12/6/16 1645	ND		ND		ND	
B9081	5	SW-5T	11/21/16 1520	12/6/16 0950	ND		ND		ND	
B9082	6	SW-6T	11/21/16 1450	12/6/16 0920	ND		ND		ND	

OUL Number	Station Number	Station Name	Date/Time Placed	Date/Time Collected	Fluorescein		Eosine		Rhodamine WT	
					Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)
B9083	7	SW-7T	11/21/16 1555	12/6/16 1150	ND		ND		ND	
B9084	8	SW-8T	11/22/16 0745	12/6/16 1235	ND		ND		ND	
B9085	9	SW-9T	11/21/16 1540	12/6/16 1125	ND		ND		ND	
B9086	10	MW-14	11/21/16 1650	12/6/16 1105	ND		ND		ND	
B9087	11	MW-15	11/22/16 0950	12/6/16 1015	ND		ND		ND	
B9418	1	SW-1T	12/6/16 1330	12/19/16 1245	ND		ND		ND	
B9419	2	SW-2T	12/6/16 1310	12/19/16 1300	ND		ND		ND	
B9420	Laboratory control charcoal blank									
B9421	3	SW-3T	12/6/16 1250	12/19/16 1320	ND		ND		ND	
B9422	4	SW-4T	12/6/16 1045	12/19/16 1200	ND		ND		ND	
B9423	5	SW-5T	12/6/16 0950	12/19/16 1120	ND		ND		ND	
B9424	6	SW-6T	12/6/16 0920	12/19/16 1045	ND		ND		ND	
B9425	7	SW-7T	12/6/16 1150	12/19/16 1435	ND		ND		ND	
B9426	8	SW-8T	12/6/16 1235	12/19/16 1400	ND		ND		ND	
B9427	9	SW-9T	12/6/16 1125	12/19/16 1420	ND		ND		ND	
B9428	10	MW-14	12/6/16 1105	12/19/16 1225	ND		ND		ND	
B9429	11	MW-15	12/6/16 1015	12/19/16 1140	ND		ND		ND	
B9867	1	SW-1T	12/19/16 1245	1/10/17 1200	ND		ND		ND	
B9868	2	SW-2T	12/19/16 1300	1/10/17 1235	ND		ND		ND	
B9869	3	SW-3T	12/19/16 1320	1/10/17 1330	ND		ND		ND	
B9870	4	SW-4T	12/19/16 1200	1/10/17 1135	ND		ND		ND	
		SW-5T		No sample collected, frozen or dry between consecutive sampling events						
B9871	5	SW-6T	12/19/16 1045	1/10/17 1100	ND		ND		ND	
B9872	6	SW-7T	12/19/16 1435	1/10/17 1400	ND		ND		ND	
B9873	7	SW-8T	12/19/16 1400	1/10/17 1305	ND		ND		ND	
B9874	8	SW-9T	12/19/16 1420	1/10/17 1345	ND		ND		ND	
B9875	9	MW-14	12/19/16 1225	1/11/17 1000	ND		ND		ND	
B9876	10	MW-15	12/19/16 1140	1/11/17 1020	ND		ND		ND	
C0136	1	SW-1T	1/10/17 1200	1/25/17 1300	ND		ND		ND	
C0137	2	SW-2T	1/10/17 1235	1/25/17 1325	ND		ND		ND	
		SW-3T		No sample collected, frozen or dry between consecutive sampling events						
C0138	3	SW-4T	1/10/17 1135	1/25/17 1245	ND		ND		ND	
		SW-5T		No sample collected, frozen or dry between consecutive sampling events						
C0139	4	SW-6T	1/10/17 1100	1/25/17 1115	ND		ND		ND	
C0140	Laboratory control charcoal blank									
		SW-7T		No sample collected, frozen or dry between consecutive sampling events						

OUL Number	Station Number	Station Name	Date/Time Placed	Date/Time Collected	Fluorescein		Eosine		Rhodamine WT	
					Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)
		SW-8T		No sample collected, frozen or dry between consecutive sampling events						
C0141	5	SW-9T	1/10/17 1345	1/25/17 1145	ND		ND		ND	
C0142	6	MW-14	1/11/17 1000	1/25/17 1230	ND		ND		ND	
C0143	7	MW-15	1/11/17 1020	1/25/17 1210	ND		ND		ND	
C0553	1	SW-1T	1/25/17 1200	2/10/17 1200	ND		ND		ND	
C0554	2	SW-2T	1/25/17 1235	2/10/17 1220	ND		ND		ND	
C0555	3	SW-3T	1/10/17 1330	2/10/17 1235	ND		ND		ND	
C0556	4	SW-4T	1/25/17 1135	2/10/17 1140	ND		ND		ND	
		SW-5T		No sample collected, frozen or dry between consecutive sampling events						
C0557	5	SW-6T	1/25/17 1100	2/10/17 1040	ND		ND		ND	
		SW-7T		No sample collected, frozen or dry between consecutive sampling events						
C0558	6	SW-8T	1/10/17 1305	2/10/17 1250	ND		ND		ND	
C0559	7	SW-9T	1/25/17 1345	2/10/17 1115	ND		ND		ND	
C0560	Laboratory control charcoal blank									
C0561	8	SW-10T	1/25/17 1400	2/10/17 1310	ND		ND		ND	
C0562	9	SW-14T	1/25/17 1415	2/10/17 1320	ND		ND		ND	