APPENDIX B-2: Hydrogeologic Investigation of the Proposed Eastern Upland UIG (Includes a July 11, 2017 Addendum Letter from Ozark Underground Laboratory)

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

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

1.0 INTRODUCTION

Hydrometrics, Inc. conducted an investigation of the groundwater system in the vicinity of the proposed eastern upland Underground Infiltration Gallery (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 of the dye tracer investigation are summarized in Sections 2 through 4.

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 to 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).

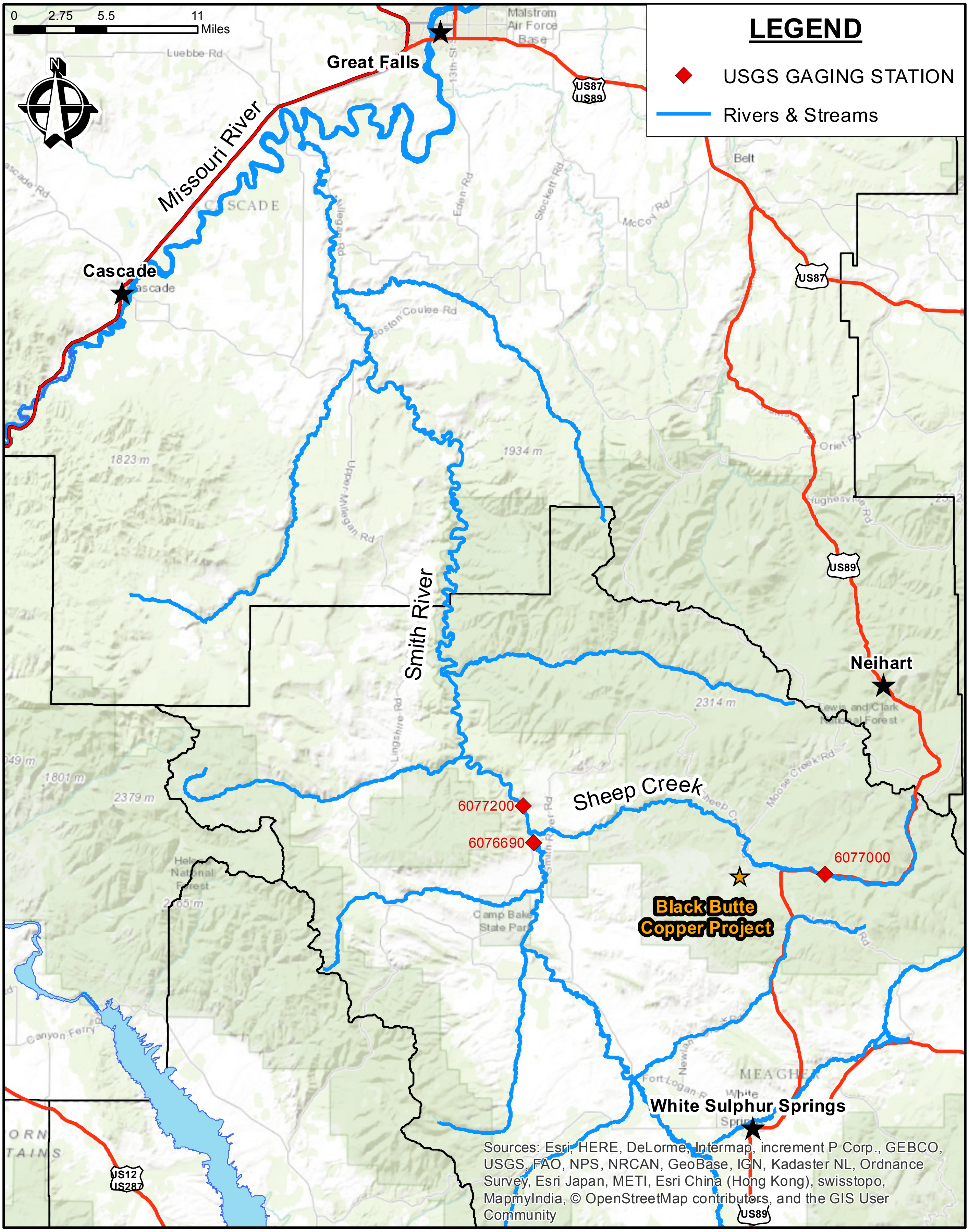

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Figure 1
Project Location Map
Black Butte Copper Project
Meagher County, Montana

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 three feet wide and four to six 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 eight to twelve inches of washed gravel, the pipe, approximately three 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. The layout eastern UIG, monitoring wells, and tracer monitoring sites are on Figure 2.

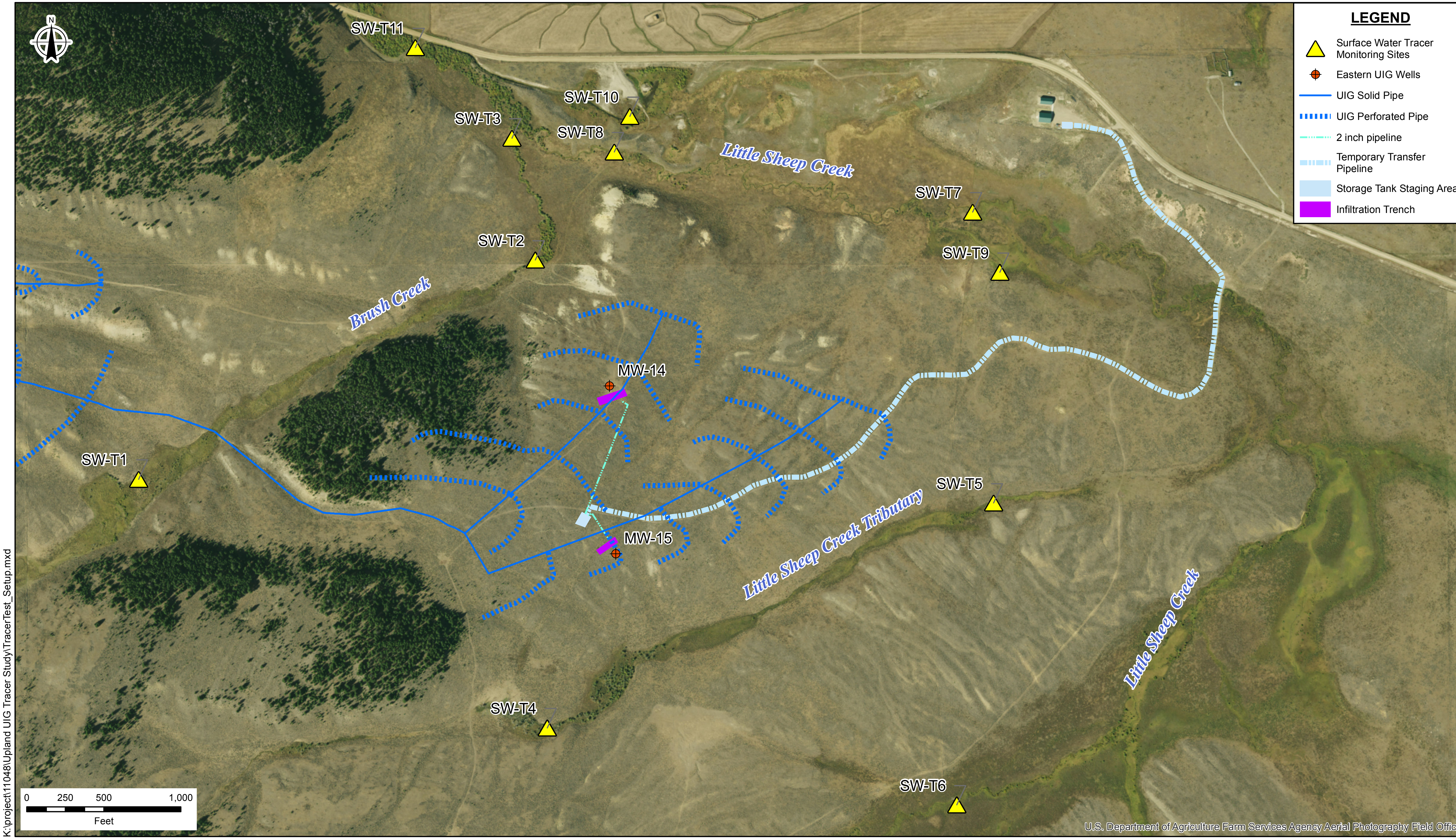

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Figure 2
UIG INFILTRATION TRACER TEST LAYOUT
Black Butte Copper Project
Meagher County, Montana

2.0 HYDROGEOLOGIC INVESTIGATION

Hydrometrics commenced the eastern UIG hydrogeological investigation in September 2016 and continues to conduct tracer monitoring at identified sampling sites (Figure 2) according to the monitoring schedule in Table 1. 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.

<u>Pneumatic Slug Test:</u> 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 four-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 (MW-14 and MW-15) in October 2016. 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.

Two trenches were excavated to approximately six feet deep, 20 feet long at their base, and three feet wide to simulate the proposed excavation for the UIG trenches. The trenches were excavated approximately ten 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 four-inch HDPE pipe and four and six-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 intended to allow 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 five-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 two-inch discharge lines, capped and oscillated to fully dissolve the dye powder in water. Five pounds of fluorescein dye (one five gallon carboy) were added to the southern infiltration trench (near MW-15) and ten pounds of dye (two five 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), 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.

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.

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

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).

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 will only be analyzed if dye is found to be present in the activated carbon sampler(s) and quantification of dye concentration is needed. During winter, 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 two-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 two-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 three to four 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 monitor well constructor 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 AND GROUNDWATER MONITORING

Water level data collected from the Easter UIG monitoring wells were used to determine groundwater mounding during infiltration, and calculate the water level elevation. Groundwater mounding was calculated as the difference between the pre-test static water level and the subsequent water-level measurements during and after infiltration. Groundwater elevations were calculated as the difference between the measuring point elevation and the static water level measurements at each well. The groundwater hydrographs are located in Figure 3. The water level elevation data collected during the fourth quarter groundwater sampling event was used to augment the project-scale potentiometric surface map, extending the coverage area to the eastern UIG (Figure 4). The potentiometric contours suggest a generally northern groundwater flow and a hydraulic gradient of approximately 0.03.

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. Mounding of 3.5 and 1.0 feet was observed at MW-14 and MW-15, respectively (Figure 5).

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 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.

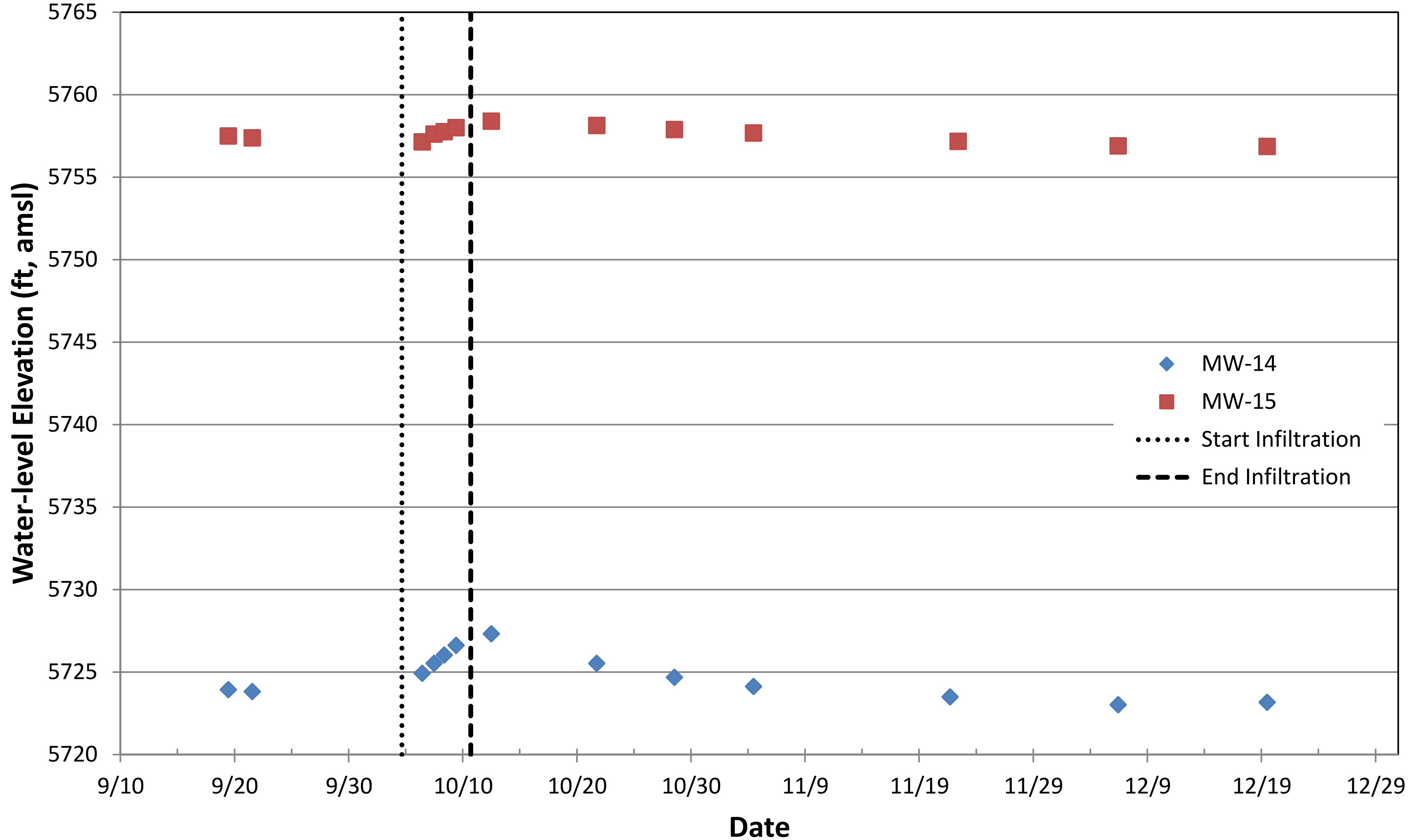

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Figure 3
2016 MW-14 and MW-15 Groundwater Hydrograph
Black Butte Copper Project
Meagher County, Montana

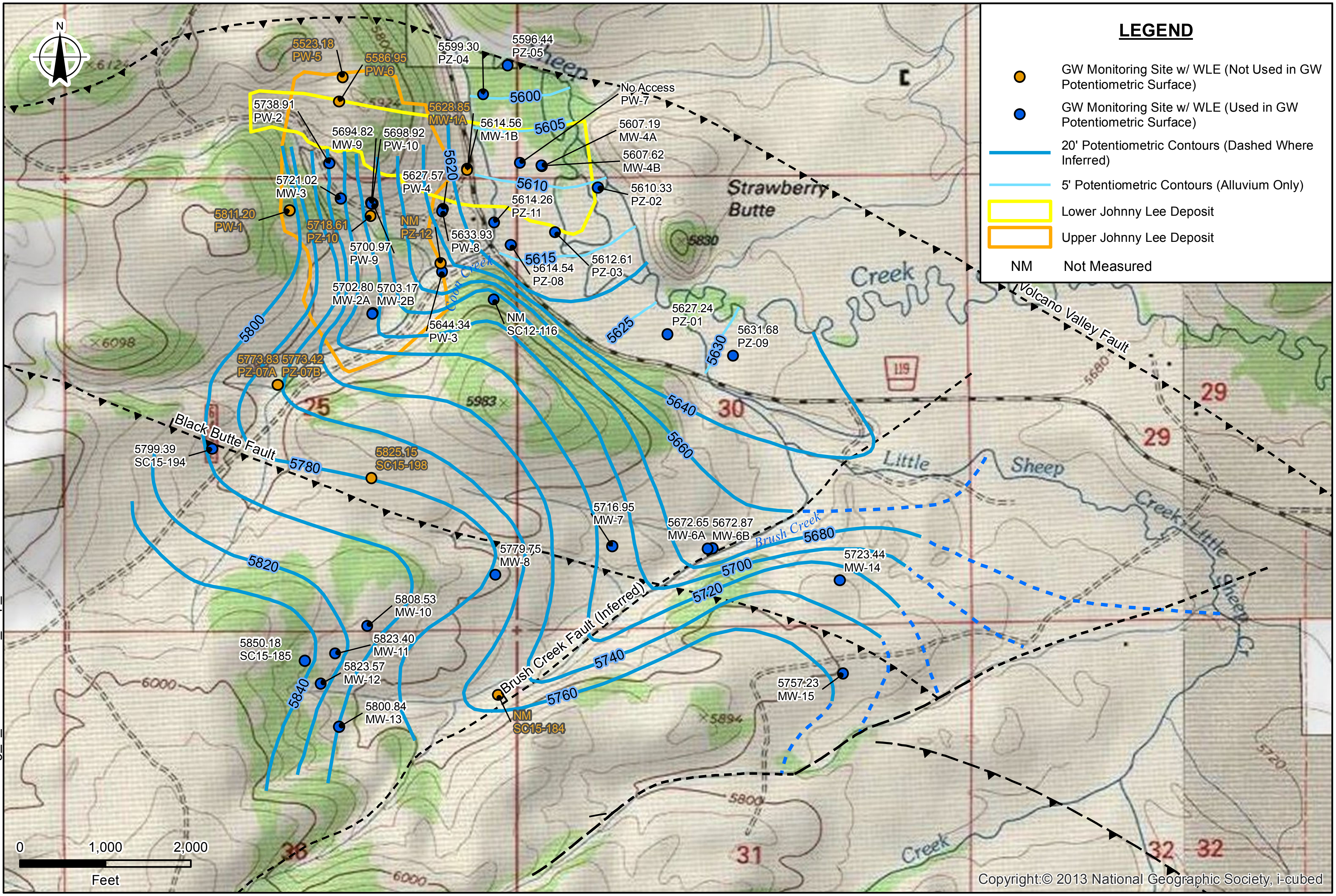

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Figure 4
November 2016 Potentiometric Surface Map
Black Butte Copper Project
Meagher County, Montana

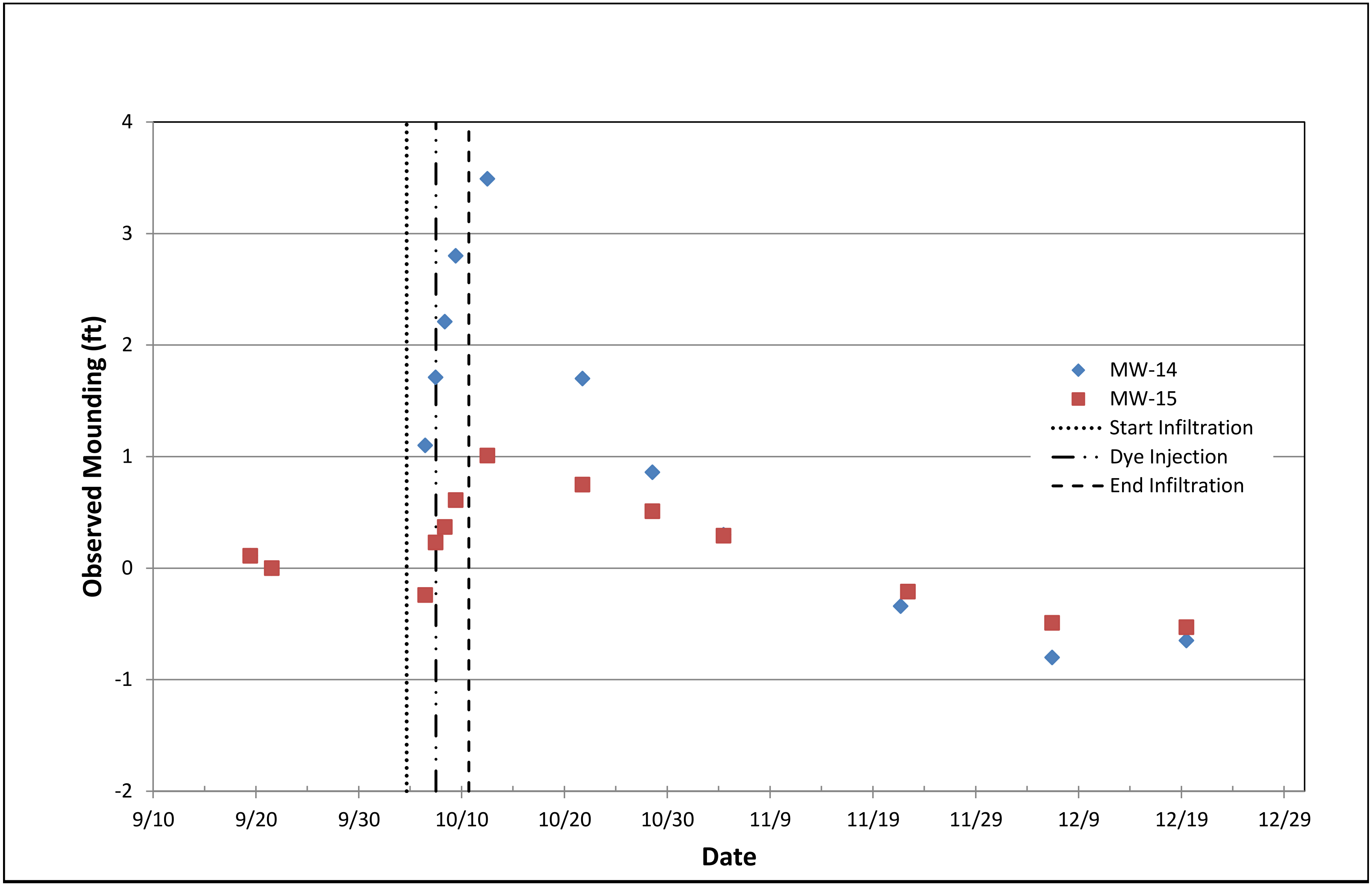

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Figure 5
Observed Mounding During Infiltration Test
Black Butte Copper Project
Meagher County, Montana

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 GROUNDWATER MOUNDING ANALYSIS

The water-level observation data collected during and after infiltration were analyzed using AQTESOLV (v.4.5) to estimate for 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 suggests that the bedrock near the water table is characterized by a higher hydraulic conductivity than the underlying bedrock; furthermore, the mounding analysis and slug test analysis collectively suggest that hydraulic conductivity decreases with depth.

3.5 TRACER MONITORING

Routine tracer sampling has shown no detectable eosine or fluorescein in any of the monitoring wells, surface water, and groundwater seeps to date. Additionally, tracer sampling has shown no 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. Wells MW-14 and MW-15 have been sampled for rhodamine following injection and though the rhodamine is visible in water samples, the laboratory results are pending. Laboratory results are included in Appendix D.

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. 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. Additionally, the gravel pit outfall (between Little Sheep Creek and the Sheep Creek Road) has remained clear of ice throughout the winter. Two additional tracer monitoring sites were added on January 25, 2017 to monitor possible dye tracers in groundwater connected to the gravel pit area; one downstream of groundwater seeps near the gravel pit outfall (SW-T11), and one at existing surface water monitoring site SW-14 (SW-T14).

Resulting from preliminary evaluations of the tracer test, principally the lack of eosine and fluorescein detections in the monitoring wells (MW-14 and MW-15), a third tracer dye was injected into the groundwater at each well on January 26, 2016. The infiltration test showed connectivity between infiltrated water and the groundwater system that MW-14 and MW-15 are completed in; however, eosine and fluorescein were not detected in groundwater at these wells. It is likely that the eosine and fluorescein tracer traveled past the monitoring wells prior to mixing with deeper groundwater at the depths of the screened intervals. Therefore, Rhodamine WT dye was injected into the screened interval of both MW-14 and MW-15 to evaluate the transport and migration of groundwater in the deeper bedrock aquifer. Conceptually, the water discharged through the UIG will infiltrate through the unsaturated zone to the groundwater table, then travel with regional groundwater according the hydraulic gradients and aquifer permeability/connectivity. The primary zone of transport will be in the first 10-20 feet of the aquifer with possible mixing to the deeper bedrock in the long-term.

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 and therefore samples have not been collected at dates specified in Appendix D.

3.6 WATER QUALITY

Water quality results from MW-14 and MW-15 are shown in Table 7. 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 results from well MW-14 detected 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.

TABLE 7. 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*

4.0 SUMMARY OF RESULTS

The hydrogeologic investigation at the eastern UIG is ongoing. To date, the investigation provides some essential information for evaluating the groundwater response to infiltration, including aquifer characterization, observed mounding, and baseline water quality. Wells MW-14 and MW-15 are completed in fractured shale bedrock of the Newland Formation, characterized by low hydraulic conductivity (0.25 to 0.33 ft/day) estimated by pneumatic slug tests. Groundwater mounding observed during infiltration was approximately 3.5 feet and 1.0 foot in wells MW-14 and MW-15, respectively. Based on groundwater mounding, the aquifer near the top of the water table has a greater estimated hydraulic conductivity (approximately 20 to 30 times) than the deeper aquifer. Water quality samples from MW-14 and MW-15 were similar to other monitoring wells completed in shallow bedrock within the project area.

Three dye tracers have been introduced to the groundwater system through infiltration (eosine and fluorescein) and direct injection into the well screened interval (rhodamine). Dye tracers are currently being monitored at a total of 13 sites; 11 sites are surface water or groundwater seeps, and two sites are monitoring wells. None of the dyes used in the tracer test have been detected at any of the monitoring sites to date. The lack of tracer at any of the sites suggests that water infiltrated in the vicinity of the eastern UIG is not in immediate and direct connection to adjacent surface water.

5.0 REFERENCES

Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

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.

Nelson, W.H. 1963. Geology of the Duck Creek Pass quadrangle, U.S. Geological Survey Bulletin 1121J, 56 p.

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

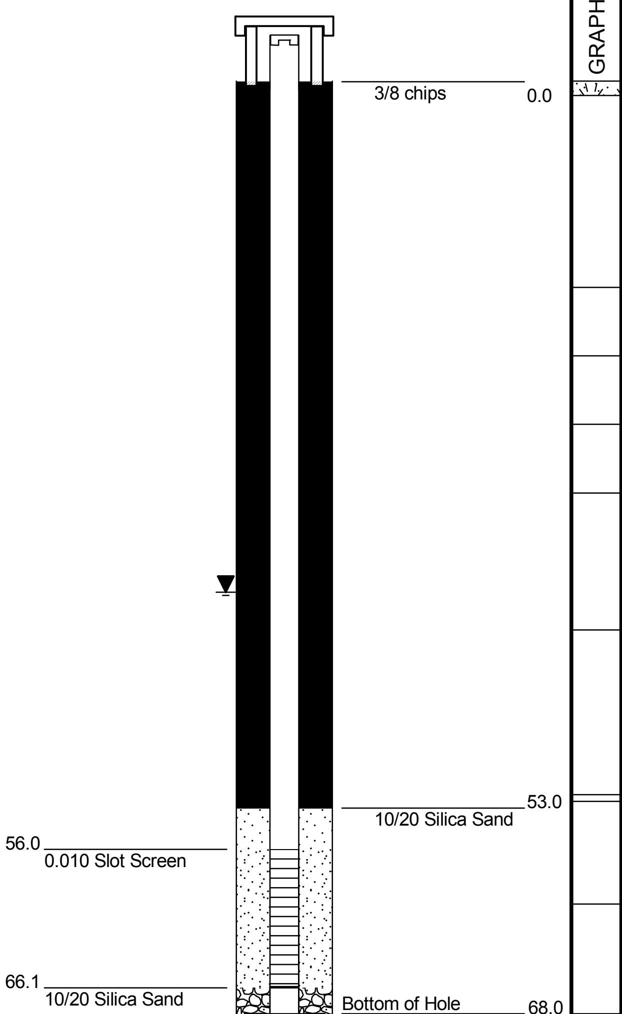
Client: Tintina Resources
Project: Black Butte Copper Project
County: Meagher State: MT
Property Owner: Holmstrom Short Ranch LLC
Legal Description: SW,SE, S30, T12N, R07E
Location Description: Eastern UIG
Recorded By: J. Harwood
Drilling Company: O'Keefe Drilling
Driller: Scott/Corey
Drilling Method: 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

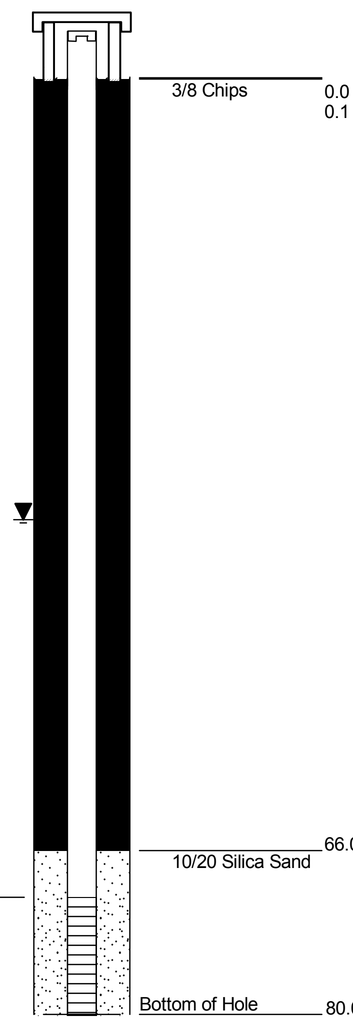
Client: Tintina Resources
Project: Black Butte Copper Project
County: Meagher State: MT
Property Owner: Holmstrom Short Ranch LLC
Legal Description: NW, NE, S31, T12N, R07E
Location Description: Eastern UIG
Recorded By: J. Harwood
Drilling Company: O'Keefe Drilling
Driller: Scott/Corey
Drilling Method: 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.

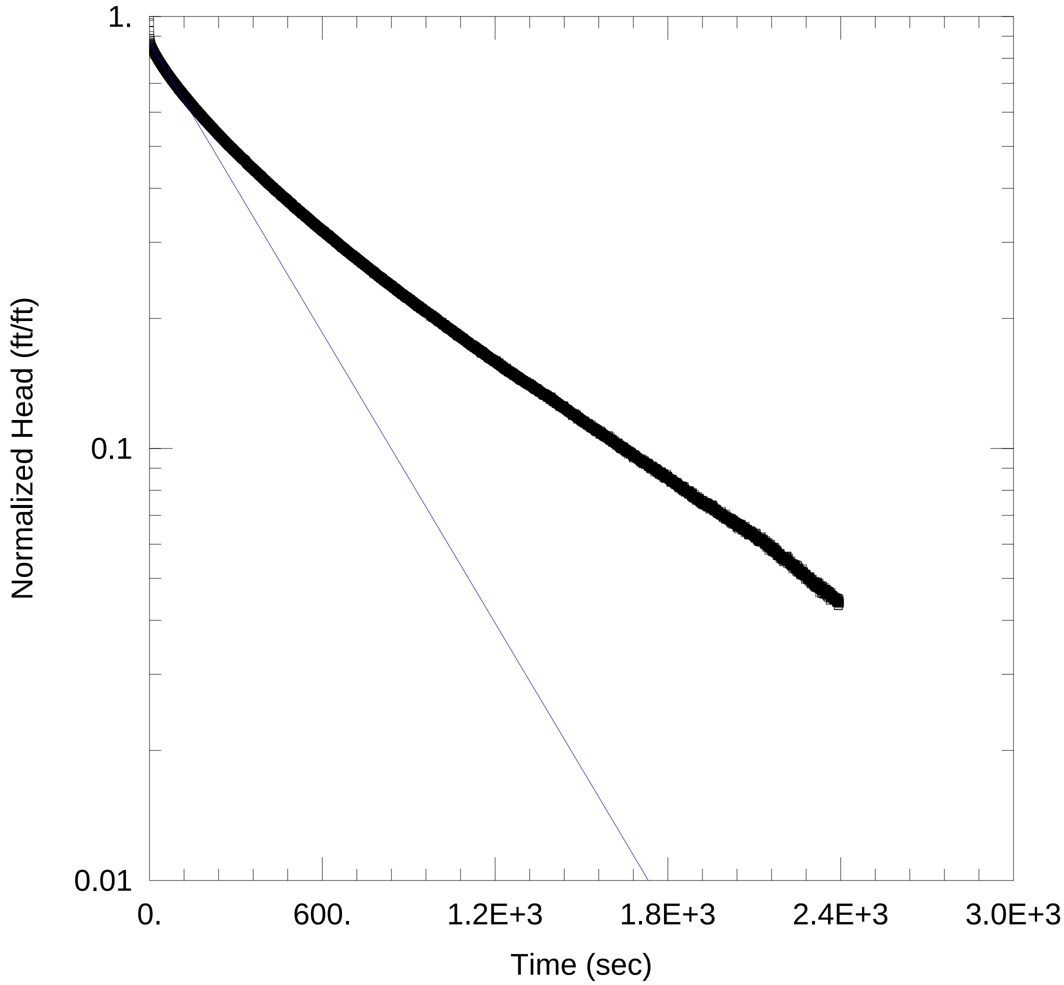
at 68 feet, encountered water upon re-entry with additional drilling rod. Wet.

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.

PVC WELL W/STEEL CASING K:\GINT\PROJECTS\11048.GPJ HYDHLN2.GDT 1/9/17

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.

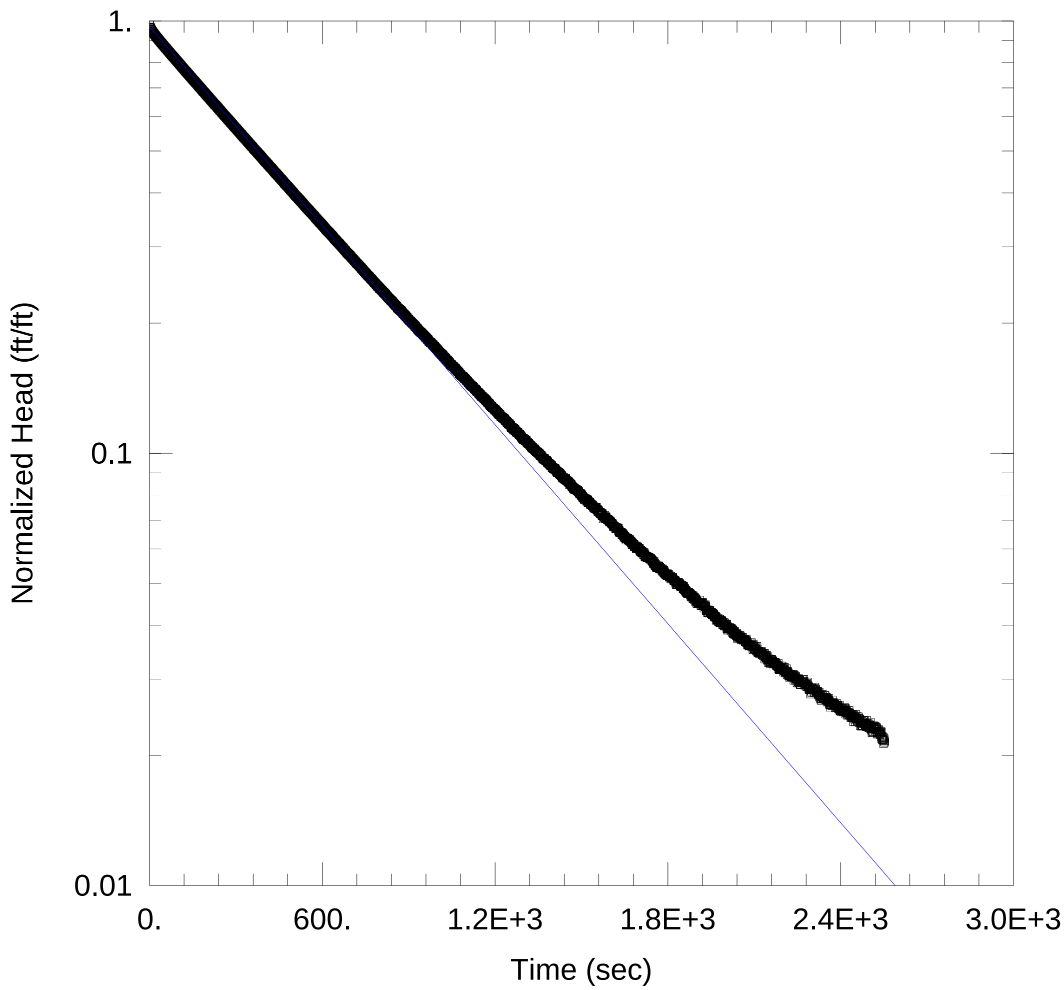
WELL DATA (MW-14)

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.

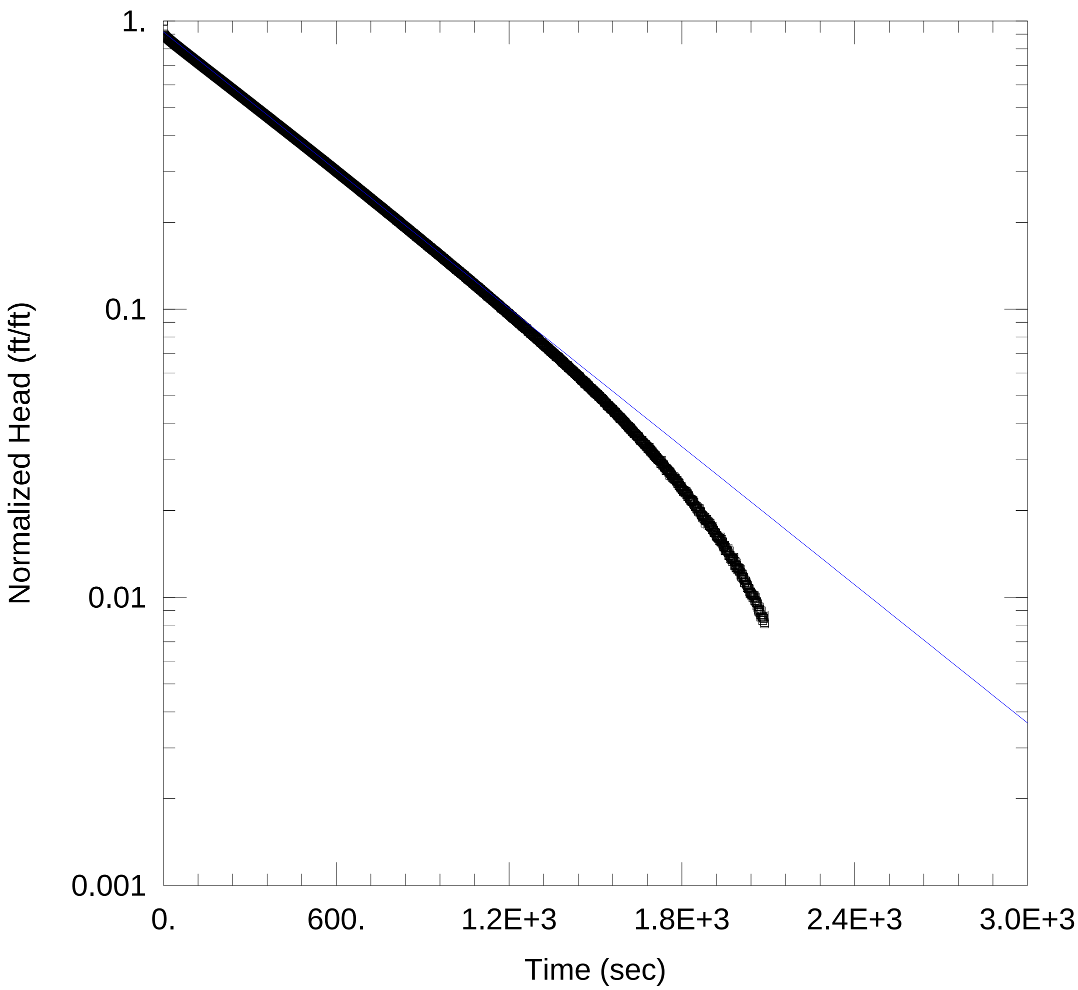
WELL DATA (MW-15)

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

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.24 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)

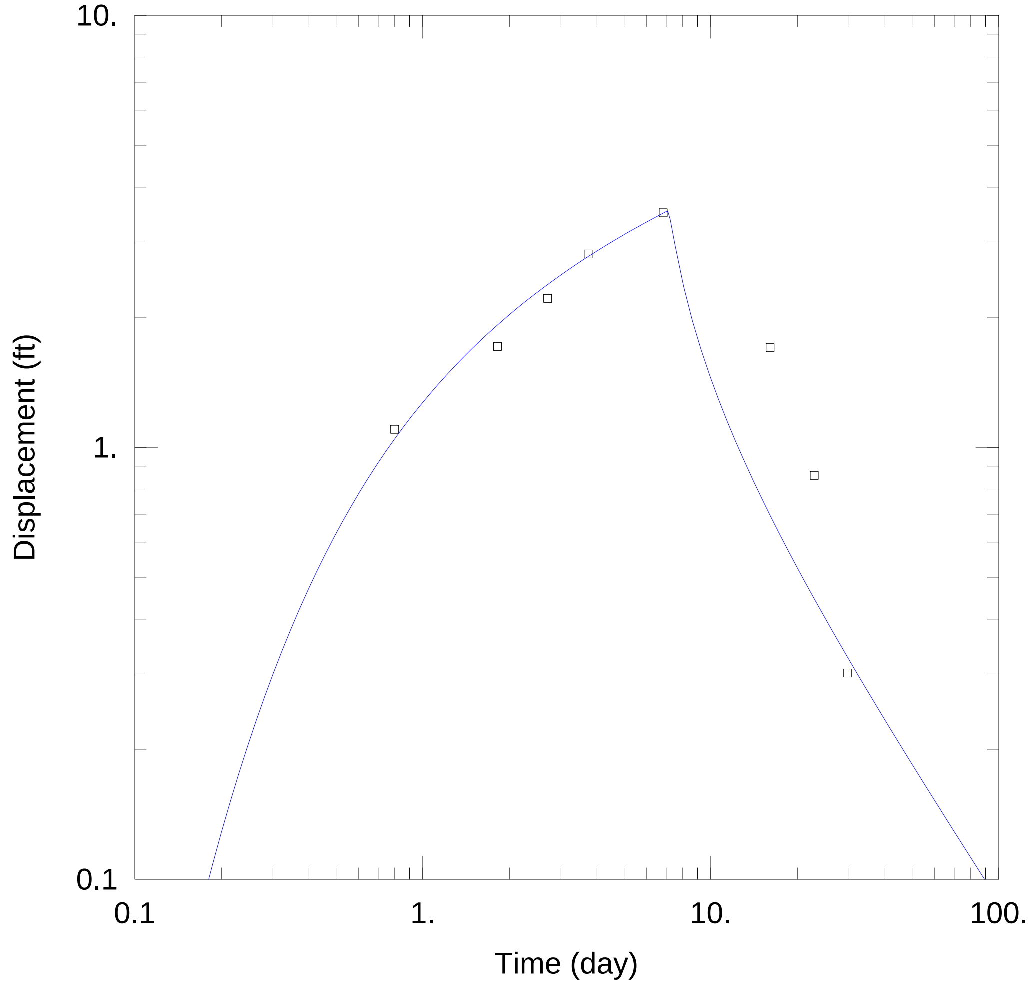
Initial Displacement: 4.95 ft
Total Well Penetration Depth: 40. ft
Casing Radius: 0.083 ft
Static Water Column Height: 0. ft
Screen Length: 10. ft
Well Radius: 0.083 ft

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

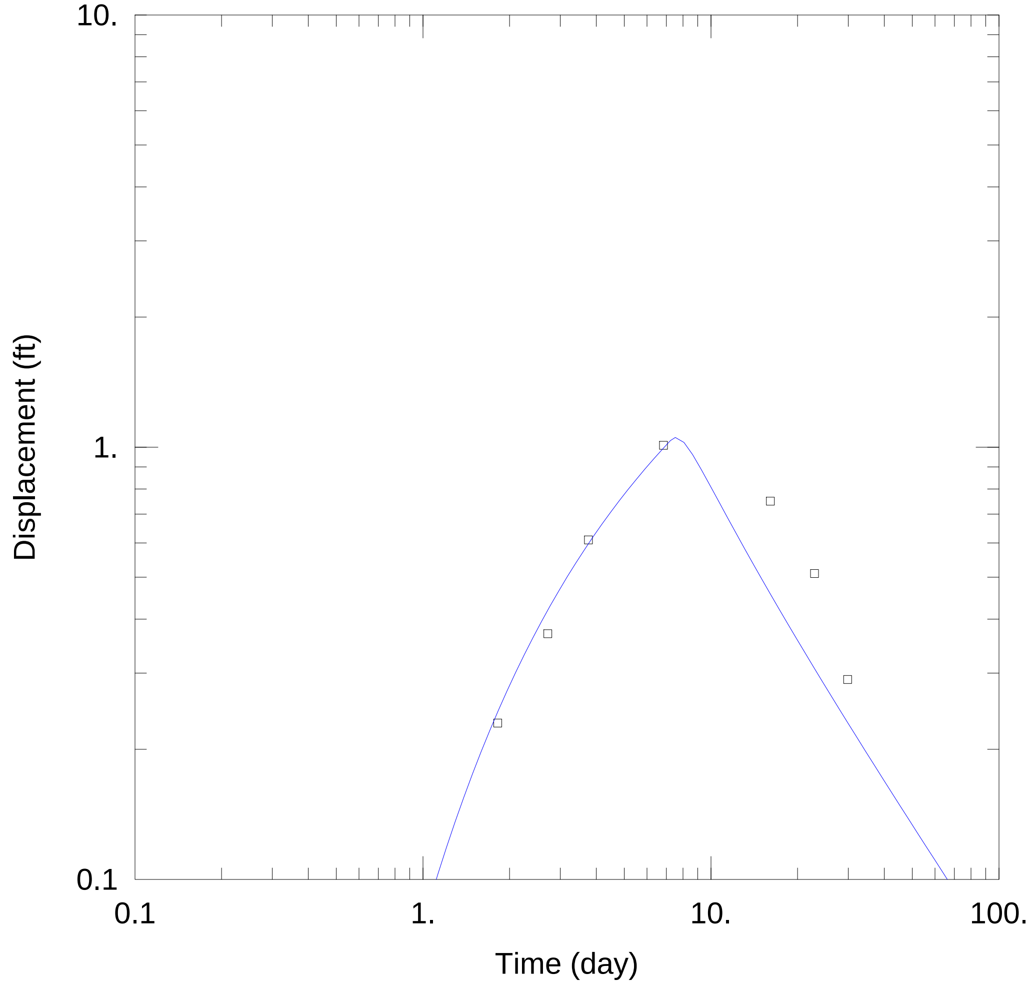
Well Name	X (ft)	Y (ft)
□ MW-14	10	0

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	

APPENDIX E

ADDENDUM LETTER BY OZARK
DATED JULY 11, 2017

Ozark UNDERGROUND LABORATORY 1572 Aley Lane • Protem, MO 65733 • (417) 785-4289 • fax (417) 785-4290 • contact@ozarkundergroundlab.com

July 11, 2017
Via email to GBRYCE@hydrometrics.com

Mr. Greg Bryce, Senior Hydrogeologist
Hydrometrics, Inc.
3020 Bozeman Avenue
Helena, MT 59601.

Dear Mr. Bryce:

Thanks for sending the paper "Adsorption of Alizarin, Eriochrome Blue Black R, and Fluorescein Using Different Iron Oxides as Adsorbents" authored by Silvina Pirillo, Maria Lajan Ferreira, and Elsa Hueda (2007). It is my understanding from speaking with you that a regulatory agency is using this paper to suggest that the fluorescein dye used in your groundwater tracing work would not be able to reach a nearby stream because iron oxides are present in the intervening dolomitic shales and could adsorb and remove fluorescein. The agency's position is incorrect for two important reasons.

First, fluorescein is a common name and is applied to several dyes with vastly different properties. A similarity in common names does not indicate a similarity in properties and uses.

The fluorescein used in groundwater tracing is the sodium salt of fluorescein. Its Color Index Name is Acid Yellow 73. A copy of its structure is shown as Figure 1. Acid Yellow 73 is <u>not</u> used in the textile industry because it is <u>not</u> a "direct" dye and does not color fabrics. It colors water. The paper by Pirillo et al. (2007) did not evaluate the dye you are using.

There is another fluorescein (Solvent Yellow 94) that is soluble in petroleum (but only slightly soluble in water). It is routinely used by mechanics to search for oil leaks in vehicles. It is also used to test for leaks during pressurized testing of underwater petroleum pipelines. Its structure is shown in Figure 2. It is not useful in water tracing.

The structure of the fluorescein evaluated in the Pirillo et al. (2007) paper was shown in figure 1 of that paper. The structure is shown in my Figure 3. Note that it differs from both of the above fluoresceins. Unfortunately, the paper by Pirillo et al. (2007) did not identify the Color Index Name for this fluorescein; this is an oversight for quality scientific reporting. This must be a "direct dye" since it is used in the textile industry; direct dyes are not useful for most groundwater tracing. As a direct dye it would be expected to have a much greater sorption tendency than the Acid Yellow 73 dye used in groundwater tracing.

In summary, the first deficiency in the agency's position is that the compound evaluated in the article is not the compound used in the groundwater tracing work.

A second deficiency in the agency's position is that the paper by Pirillo et al. (2007) is evaluating synthetic iron oxides, not iron oxides in place in geologic formations in place for millions of years. As identified in the paper the synthetic compounds are specifically processed to facilitate strong sorption of compounds such as the fabric dyes. In the case of the synthetic goethite its multi-step processing included 72 hours in a vacuum oven at 65 degrees C (that is about 149 degrees F). This step would greatly increase the activation of the iron compound. As a comparison, our sampling for tracer dyes places primary reliance on activated charcoal samplers. This activated carbon is extensively processed to make it capable of adsorbing multiple compounds such as dyes. "Natural" charcoal, such as used for barbeques, it not activated and does not function as an adsorbing medium. Suggesting that naturally in-place iron compounds would behave in a fashion similar to synthetic iron compounds is an unsupported and illogical extension of limited data of negligible relevance.

I have done extensive (and successful) groundwater tracing work in iron rich environments using the fluorescent tracer dyes, and especially fluorescein (the Acid Yellow 73 one). This has included tracing through abandoned coal mines with extensive deposits of "yellow boy" (iron hydroxides) and through open pit and underground workings in an abandon iron mine. In the case of coal mines the greatest problem in tracing is typically low pH values (sometimes less than 2) since this change the structure of some of the dyes to compounds that are more readily adsorbed onto the yellow boy.

In conclusion, the agency challenge to your tracing work based on the paper by Pirillo et al. (2007) is not credible. First, that paper did not evaluate Acid Yellow 73, which was the dye you used in the tracing work. The agency has compared apples and oranges. Second, the suggestion that natural iron compounds would have sorption characteristics approaching, or similar to, synthetic iron compounds is illogical and without technical merit. Your work has shown that none of the dye you introduced has reached the nearby stream during the period of sampling; the agency needs to accept that as a valid finding.

Sincerely,

Thomas Aley, PHG & PG
Senior Hydrogeologist and President
Ozark Underground Laboratory, Inc.

References

Aley, Thomas. 2002. Ozark Underground Laboratory's groundwater tracing handbook. Protem, MO. 35p.

Pirillo, Silvina; Maria Lujan Ferreira; and Elsa H. Rueda. 2007. Adsorption of Alizarin, Erinchrome Blue Black R, and fluorescein using different iron oxides as adsorbents. Indus. Eng. Chem. Res. Vol 46, pp. 8255-8263.

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Figure 1. Structure of Fluorescein (Acid Yellow 73) introduced by Hydrometrics and supplied by Ozark Underground Laboratory, Inc.

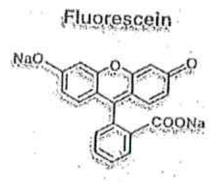

Figure 2. Structure of fluorescein (Solvent Yellow 94). This dye is soluble in solvents but only slightly soluble in water. Source: www.dyeworld.com

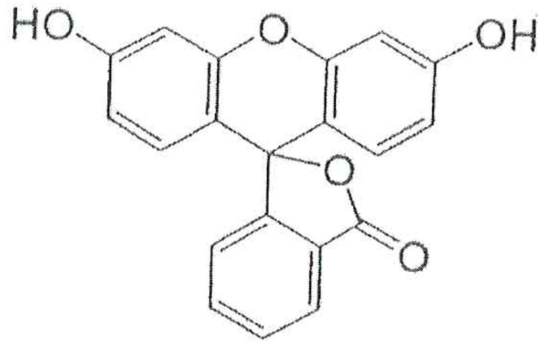

Figure 3. Structure of the fluorescein evaluated by Pirillo et al. (2007) and used to color textiles. Source: Pirillo et al. (2007, figure1).